



AMERICAN

FERN JOURNAL

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QUARTERLY JOURNAL OF THE AMERICAN FERN SOCIETY



VOLUME 107

NUMBER 4

OCTOBER-DECEMBER 2017



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Ceradenia spectabilis (Polypodiaceae), a New Species from Cerro del Torrá, Colombia

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ABSTRACT.—*Ceradenia spectabilis*, a new species, is described from Cerro del Torrá, an isolated peak in western Colombia well known for harboring rare and narrowly distributed species of plants. The new species is readily distinguished from its congeners by its broadly alate petiole and rachis, creeping rhizome with widely spaced leaves, and large oblanceolate leaves with elongate and ascending pinnae. Three other species, *C. curvata*, *C. discolor*, and *C. pearcei*, share characteristics in common with *C. spectabilis* including thick sub-spongy laminae that are sparsely setose (or setae absent), provided throughout with whitish waxy glands, alate petioles and rachises, setose rhizome scales that are also provided with a few whitish waxy glands, and sub-marginal sori. However, *Ceradenia spectabilis* can be distinguished from each of them by its longer petioles (4–6 cm long vs. 2 cm or less), broader petiole wings (2.5–3.5 mm wide vs. 0.5 cm or less), and longer pinnae (up to 10 cm long vs. 4 cm long or less). *Ceradenia spectabilis* is known only from the type, despite extensive investigations in herbaria housing large collections of Colombian ferns. This new species brings the total number of *Ceradenia* species in Colombia to 25, and ca. 74 world-wide.

KEY WORDS.—Chocó; biodiversity; endemism; taxonomy; Polypodiaceae

Cerro del Torrá is an isolated mountain peak (summit 2800 m) in the western cordillera (Cordillera Occidental) in Dept. Chocó, Colombia. It is one of four peaks in the Cordillera de San Miguel, which is separated from the Serranía de los Paraguas (a branch of the Cordillera Occidental) by a valley that drops to 600 m elevation (Silverstone-Sopkin and Ramos-Perez, 1995). These are among the wettest and most species-rich areas in the world for plants (Gentry, 1986). Cerro del Torrá and the Serranía de los Paraguas are particularly rich in rare and narrowly restricted species (Silverstone-Sopkin and Graham 1986; Davidse and Clarke, 1996; Taylor, 1997; Struwe, 2003; Pedraza 2008; Sundue, 2011; Sanin 2014; Øllgaard, 2016). By my accounting, Cerro del Torrá is the type locality for 32 plant species including the one that is described here. Endemicity, however, is not particularly high. Silverstone-Sopkin and Ramos-Perez (1995) found that only 5.2 percent of identified or new species were restricted to the mountain itself. Some of these species eventually may be better characterized as endemic to the Chocó biogeographic region or the Cordillera de San Miguel rather than Cerro del Torrá following further study of this little-explored region. Much of our knowledge of the flora is based primarily on the results of the three expeditions led by Silverstone-Sopkin and Ramos-Perez, and the Chocó region remains remote and difficult to access region of Colombia.

Among ferns, Cerro del Torrá is the type locality for *Pityrogramma opalescens* Sundue, a morphologically aberrant species in the genus, described from material at NY (Sundue, 2011). Further exploration of backlog collections at NY has led to the discovery of yet another new species from Cerro del Torrá, this time in the genus *Ceradenia*. In both cases, the new species probably remained undetected because unlike most duplicates made during the expeditions, these particular numbers were not distributed beyond CUVIC and NY (Silverstone-Sopkin, pers. comm.).

Ceradenia is a primarily neotropical genus of Polypodiaceae subfamily Grammitidoideae Parris & Sundue (Bishop, 1988; Parris, 2005; Sundue et al., 2014; PPG I, 2016; Bauret et al., 2017). Grammitidoideae (often referred to as “grammitids”) are a clade of about 900 species known for their frequently dwarfed sizes and narrow ecological niches (Parris, 1990; Ranker et al., 2004; Sundue et al., 2014; Sundue et al., 2015). Grammitid genera can be readily diagnosed by a combination of characters from the scales (clathrate or non-clathrate), hydathodes (present or absent), setae (present or absent), and other characteristics of their minute branched hairs (Sundue, 2010). Although all or nearly all Polypodiaceae have minute branched hairs, those of the grammitid genera often bear specialized cells such as glands or acicular cells that serve as powerful diagnostic characters. In fact, minute branched hairs bearing whitish waxy glandular cells are both necessary and sufficient to diagnose *Ceradenia* L. E. Bishop (Bishop, 1988; Parris, 2005; Sundue et al., 2010). Anhydathodous laminae and castaneous rhizome scales are perhaps the other most reliable characters defining the genus, however occasional species break these rules (e.g., *C. jungermanioides* (Klotzsch) L.E. Bishop lacks rhizome scales and *C. tryonorum* B. León & A. R. Sm. has hydathodes).

With its 73 currently recognized species, *Ceradenia* is the largest of the primarily neotropical genera in the Polypodiaceae subfamily Grammitidoideae (PPG I, 2016). In fact, it is the third largest genus in the subfamily, after *Oreogrammitis* Copel. (126 spp.) and *Prosaptia* C. Presl (86 spp.) (Parris, 2010; PPG I, 2016). This may be surprising even to those familiar with the neotropical fern flora since *Ceradenia* is, in general, poorly collected and characterized by rare species with narrow distributions (Kessler and Smith 2008; Mostacero, 2013; Labiak and Pereira 2016). Most of the species occur as epiphytes often on large trees in thick moss mats or in recesses and are easily overlooked. At the time of writing, there were 2,711 occurrence records for *Ceradenia* on GBIF (2017a). As a point of comparison, the generally more conspicuous grammitid genus *Melpomene* A. R. Sm. & R. C. Moran which often occurs terrestrially on roadside ledges or epiphytically in exposed places was known from 6,360 occurrence records (GBIF 2017b), despite it having only 29 recognized species (Lehnert, 2013).

Ceradenia was treated in the Flora of Colombia floristic series by León-Parra (2012) who recognized 24 species. With this new species, Colombia can be said to harbor 25 species of *Ceradenia*, and is the center of greatest diversity for the genus compared with other regions (Morton, 1967; Proctor, 1985; Tryon and Stolze, 1993; Smith 1995; Bishop and Smith 1995; León and Smith 2003; Parris

2005; Labiak and Condack, 2008; Kessler and Smith 2008; Kroemer et al., 2013; Labiak and Pereira, 2016; Sundue 2017).

Ceradenia spectabilis Sundue, sp. nov.

TYPE: COLOMBIA. Departamento Chocó, Municipio Sal José del Palmar, Cerro del Torrá, 4°46'N 76°29'W, vertiente occidental, hoyá del Río Negro, vereda de Río Negro, ca. 1 hora abajo del helipuerto, 1800–1900m, 23 August 1988, *J.E. Ramos, P.A. Silverstone, L.H. Ramos et al.* 1460 (Holotype: NY!; Isotype: CUV, image seen) (Fig. 1).

Diagnosis.—Similar to *Ceradenia pearcei* but differing by longer pinnae and broader petiole wings.

Plants epiphytic; rhizomes 2–4 mm wide, radially symmetrical, creeping; rhizome scales $2\text{--}3.5 \times 0.2\text{--}0.5$ mm, lanceolate, castaneous, lustrous, the cells turgid, the margin setose and glandular, the setae 0.2 mm long, hyaline, the glands 0.1 mm long, whitish; leaves arranged helically, widely spaced, 5–10 mm apart, $20\text{--}28 \times 6\text{--}9$ cm, provided throughout with appressed, minute branched hairs, 0.1 mm long, producing a whitish wax from glandular cells; petioles 4–6 cm long, with two vascular bundles, the cortex provided with dark sclerenchyma, this immersed in laminar tissue and not visible, broadly alate, 2.5–3.5 mm wide, the base of the petiole setose, the setae ca. 1 mm long, reddish, terete, multicellular, spreading; rachis broadly alate, the wings continuous with those of the petiole and confluent with the pinnae, internally with dark sclerenchyma, this entirely immersed in the laminar tissue and not visible; laminae thick, broadly oblanceolate, deeply 1-pinnatifid, with 20–25 pinnae pairs, the lamina base abruptly reduced, the lamina apex acute, pinnatifid or more often with a conform apical pinna, lamina tissue sub-spongiose, with large air spaces between cells; pinnae up to 10×0.5 cm, linear, widest at the base, medial pinnae long, spreading, the proximal pinnae straight, the distal pinnae falcate, the reduced to ca. 0.5 cm long; veins not visible; hydathodes absent; sori sub-marginal, slightly elongate, present along the entire length the pinnae, in ca. 20 pairs; sporangia well developed, non-setose; paraphyses present, filiform, branched, provided with minute glands producing a whitish wax; spores trilete, well developed.

Distribution.—Known only from the type collection made between 1800–1900 m in cloud forest on Cerro del Torrá, in Chocó, Colombia.

Etymology.—The epithet is derived from the Latin word *spectabilis*, meaning notable or remarkable, and was chosen in reference to the handsome eye-catching fronds of the new species.

Discussion.—*Ceradenia spectabilis* appears to be known only from the type collection despite visits to numerous herbaria with substantial holdings of Colombian ferns over the past ten years since I became aware of this species (COL, F, FMB, HUA, MO, NY, UC, US, QCA). Given the remote location of the type locality, it is unlikely that additional material resides undetected in herbaria.



FIG. 1. *Ceradenia spectabilis*, habit, Ramos et al., 1460 (NY). Scale bar = 1 cm.

Phylogenetic analyses (Sundue et al., 2010, 2014; Bauret et al, 2017) corroborate the recognition of *Ceradenia* subg. *Ceradenia* and Subg. *Filicipecten* proposed by Bishop (1988) on the basis of stipe, rhizome, and indument characters. The radially symmetrical rhizome, short petiole, and whitish glandular hairs distributed across the lamina place *C. spectabilis* in subg. *Ceradenia*.

Ceradenia spectabilis is readily distinguished from its congeners by its broadly alate petioles and rachises, creeping rhizomes with widely spaced

leaves, and large oblanceolate leaves with elongate and ascending pinnae. Three species, *C. curvata* (Sw.) L.E. Bishop, *C. discolor* (Hook.) L.E. Bishop, and *C. pearcei* (Baker) L.E. Bishop, share characteristics in common with *C. spectabilis* including thick sub-spongiose laminae that are sparsely setose (or setae absent), provided throughout with whitish waxy glands, alate petioles and rachises, setose rhizome scales that are also provided with a few whitish waxy glands, and sub-marginal sori. *Ceradenia spectabilis* can be distinguished from each of them by its longer petioles, (4–6 cm long vs. 2 cm or less), broader petiole wings (2.5–3.5 cm wide vs. 0.5 cm or less), and longer pinnae (up to 10 cm long vs. 4 cm long or less). *Ceradenia curvata* is limited to the West Indies where it is known from the Greater Antilles except Puerto Rico, and Guadeloupe and Dominica in the Lesser Antilles (Proctor, 1985). *Ceradenia pearcei* is found in the Andes from Colombia to Bolivia. *Ceradenia discolor* is also primarily Andean, but is less common, and known from Venezuela, Peru, Bolivia, and Guyana. These four species together are perhaps each other's closest relatives, but this hypothesis should be tested phylogenetically.

Because the Chocó floristic province extents northwards into Central America, *C. spectabilis* should be looked for north of Colombia as well. Users of the Flora Mesoamericana treatment, which covers that region, will find that *C. spectabilis* would key out with *C. podocarpa* and *C. fucooides*. *Ceradenia podocarpa* differs by having sori born on small marginal lobes, and *C. fucooides* differs by having pinnae 1–4-pinnatifid.

ACKNOWLEDGEMENTS

I thank Susan Fawcett for providing the illustration; Robbin Moran (NY), Julian Mostacero (VEN), and Alan Smith (UC), for taxonomic discussions of *Ceradenia* in the northern Andes; and Philip Silverstone-Sopkin for information regarding specimens at CUVC. Weston Testo and two anonymous reviewers provided useful comments on the manuscript.

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Ethnobotany of Lycophyta and Polypodiophyta in Priority Terrestrial Regions of Oaxaca, Mexico

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ABSTRACT.—Lycophyta and Polypodiophyta have been used by humans worldwide since ancient times, yet little has been documented. This paper analyzes and discusses the different uses of these plants in three Priority Terrestrial Regions (PTR) of conservation in the state of Oaxaca in Mexico. Our objectives were to: 1) document the traditional knowledge and uses of Lycophyta and Polypodiophyta among ethnic and mestizo groups; 2) analyze the variation in the use of taxa among these ethnic and mestizo groups, in terms of altitudinal distribution and type of vegetation in habitats supporting these species. Fifty species and two varieties of useful Lycophyta and Polypodiophyta from 29 genera and 15 families, were recorded. Mazatecs, Zapotecs, and Mixes are the ethnic groups with the greatest number of records of useful species from these taxonomic groups. More than 68% of such species are recognized with common names in the local languages. There are two conditions of useful plants: 1) among species used by at least four ethnic groups, how do the uses vary from two to four; 2) related to species with at least four categories of use, which are used by few ethnic groups. More than half of the species are named in at least one language, which reinforces the fact that species are recognized, valued, and important in people's daily lives, including traditional ceremonies, beliefs. Eight categories of use were documented, with medicinal, ornamental, and handcraft being the most represented. 80% of the useful Lycophyta and Polypodiophyta were distributed above 1000 masl, mainly in montane cloud forest, *Quercus* forest and *Quercus-Pinus* forest.

KEY WORDS.—distribution, ethnic groups, ferns, Mexico, traditional uses.

Oaxaca is the state in Mexico with the greatest diversity of species in Lycophyta and Polypodiophyta. Of the 1,009 Mexican species, 627 (62%) have been recorded from Oaxaca (Tejero-Díez and Mickel, 2004). Taxa are grouped within 112 genera, with the highest number of species found in *Asplenium*, *Thelypteris*, and *Selaginella*. Despite this diversity at the state level and the fact that many species are concentrated in some regions within the state (e.g., Ixtlán-Sierra Norte, 378 species; Mixe, 228; Villa Alta, 220; Tejero-Díez and

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Mickel, 2004), there are few records or reports concerning traditional knowledge and uses of these plants in Mexico.

World literature on the traditional uses of pteridophytes is quite extensive and includes reports of them in the context of both a general ethnobotanical survey—including a wide range of plant families (e.g., Barku, Opoku-Boahen, and Dali, 2014; Bellia and Pieroni, 2015)—or a more specific survey about the traditional uses of ferns and lycophytes (Murillo, 1983; Muñiz-Díaz de Leon, Mendoza-Ruíz de León, and Pérez-García, 2007; Navarrete *et al.*, 2006, Singh and Khare, 2011). In contrast, there are only a few specific studies on the ethnobotanical aspects of Mexican ferns, such as that of Gallardo-Pérez *et al.* (2006), who studied the uses of four “horsetail” species: *Equisetum hyemale* L., *E. laevigatum* A. Braun, *E. myriochaetum* Schldtl. & Cham., and *E. robustum* A. Braun ex Engelm. Although these plants were used during wood carving and for polishing soft metals, their most common use was in medicine to cure kidney illness and stomach pain, among other diseases.

Ferns and lycophytes represent an important component in traditional medicine, handcrafting, and magic-religious practices. For Oaxaca, Solano-Vargas (2008) published an ethnobotanical study of vascular plants in the municipality of Putla, Guerrero, recording four ferns used for medicinal purposes (*Elaphoglossum ipshookense* Mickel, *Equisetum giganteum* L., *Macrothelypteris torresiana* [Gaudich.] Ching, and *Selaginella* sp.), two for religious festivities (*Lycopodium clavatum* L., *Odontosoria schlechtendalii* [C. Presl] C. Chr.), and one for ornamental purposes (*Pleopeltis crassinervata* [Fée] T. Moore). For the Cuicateca region, two studies report uses of ferns and lycophytes: Solis-Rojas (2006) in the municipality of San Lorenzo Pápalo noted six species used for ornamental (*Adiantum capillus-veneris* L., *Asplenium* sp., *Myriopteris* sp. [= *Cheilanthes*]), fodder (*E. hyemale*), and medicinal (*E. hyemale* and *Selaginella lepidophylla* [Hook & Grev.] Spring) purposes; and in Santos Reyes Pápalo, Mercado-Gonzalez (2013) provided an analysis of the local commercialization of medicinal plants, including four ferns (*Athyrium* sp., *Elaphoglossum* sp., *Equisetum* sp., and *Polypodium* sp.). Finally, the database of traditional uses and management of flora (Caballero *et al.*, 2004) reports *Lycopodium* sp. (Lycopodiaceae), *Selaginella pallescens* (C. Presl) Spring (Selaginellaceae), and *Sphaeropteris horrida* (Liebm.) R. M. Tryon (Cyatheaceae) as useful species. Other ethnobotanical studies include ferns as part of a long list of useful plants, including gymnosperms and angiosperms (e.g., Muñiz-Díaz de León *et al.*, 2007).

The objectives of the present study were to: 1) document the traditional knowledge and uses of Lycophyta and Polypodiophyta among ethnic and mestizo groups located in three priority terrestrial regions (PTRs) in the state of Oaxaca and 2) analyze variations in the use of taxa among these ethnic and mestizo groups in terms of their altitudinal distribution and the other types of vegetation present where these species grow.

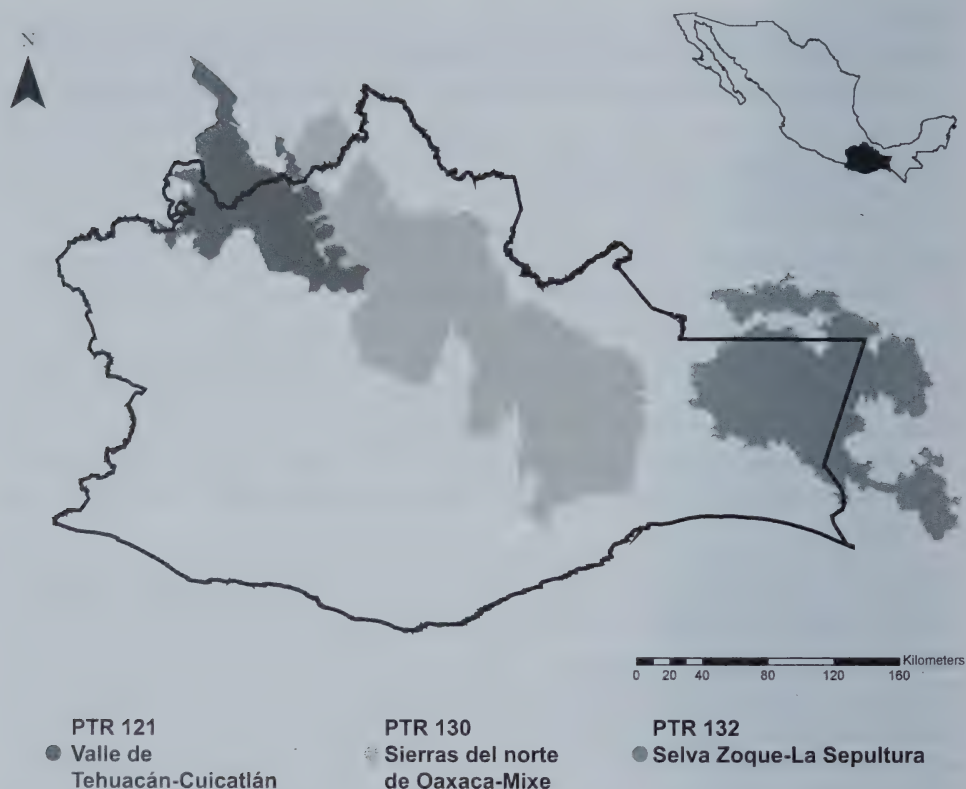


FIG. 1. Study area in the state of Oaxaca, México.

MATERIALS AND METHODS

Study area.—The study area comprised 85 municipalities (Figure 1) belonging to three of the seven priority terrestrial regions (PTRs) proposed by Arriaga *et al.* (2000) for the state of Oaxaca, and occupied by the following ethnic groups: PTR 121 (Valle de Tehuacán-Cuicatlán), inhabited by Cuicatecs and Mazatecs; PTR 130 (Sierras del Norte de Oaxaca-Mixe) inhabited by Zapotecs, Mixes, Chinantecs, Nahuas, and Mixtecs; and PTR 132 (Selva Zoque-La Sepultura), inhabited by Zoques. This area also included four municipalities with mestizo populations (San Pedro Teutila, Natividad, Santiago Xiacuí, [PTR 130], and San Pedro Tapanatepec [PTR 132]). A number of the municipalities inhabited by each ethnic group were highly variable because the original project was designed at a PTR level (Figure 1).

Voucher specimens and ethnobotanical information.—In each municipality, the project was made known to the authorities (i.e., the municipality president and communal landlords) in order to inform and request authorization to explore the community to collect plant specimens and to get the support of local guides who knew the area, the plants, and their names in the local or Spanish language. We also obtained permission to collect plants in preserved

or sacred areas or in places that have special ecological importance (e.g., near waterfalls, archaeological sites, and glens). In virtually all cases, an official document of the Universidad Autónoma Metropolitana was presented, and the stamp of each municipality was solicited. Within each municipality, we asked for one local guide, and we emphasized the necessity that they know the traditional uses of wild plants, as well as their common names, in Spanish or in the local language. Local authorities looked for these persons, who ranged in age from 20–65 years old. Most of the local guides were men; only four municipalities had female local guides.

Fieldtrips of 10–12 days every two months were conducted for three years to collect plants in the 85 municipalities that were proposed in the original project (Rendón-Aguilar *et al.*, 2017). Each municipality was visited once. Due to these logistical limitations, in many cases, local guides noted ethnobiological species that were not mature at the time of the fieldwork and were neither collected nor recorded.

Each specimen that was recognized by local guides as useful was photographed and collected, and ecological and geographical data were recorded, including date, town, village, geographic coordinates, altitude, vegetation type (according to the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad-Comité Asesor del Proceso de Montreal-Instituto Nacional de Estadística, Geografía e Informática (CONABIO-CAPM- INEGI, 2002), soil characteristics, biological data of each species (habitat, size, biological form, size, characteristics reproductive structures), common name(s), use(s), (categories), parts of plants used, and descriptions of use. All specimens were numbered, placed temporarily in brown paper bags, and later processed appropriately for transportation. Once in the laboratory, specimens were mounted for preservation in museum collections.

Identification of plant specimens.—Specimens were reviewed and identified with specialized keys (Mickel and Smith, 2004). The main specimen was assembled, labeled, and deposited in the metropolitan herbarium (UAMIZ) of the Metropolitan Autonomous University, Iztapalapa. Duplicates were distributed to herbaria of the National Autonomous University of Mexico (MEXU) and the Interdisciplinary Research Center for Integral Development Regional unit of Oaxaca (CIIDIR Herbarium-Oaxaca). Photographs of specimens taken in the field and the surrounding vegetation were captured in color with a minimum resolution of 300 dpi, and images were deposited in the image bank of CONABIO.

Information processing.—The information for each specimen was integrated into the database BIÓTICA © 5.0.3 (CONABIO, 2012), along with photographs of the specimens.

Data analysis.—Data were analyzed from three perspectives: (1) Ethnobotanical: Number of useful species, genera and families of Lycophyta and Polypodiophyta, categories of use, useful part of the plant (when it was indicated), number of species/ethnic group, common name (local language and/or Spanish), (2) geographical: distribution-based on comparisons with previous studies about plant diversity of Oaxaca (García-Mendoza *et al.*, 2004;

García-Mendoza and Meave, 2012), and (3) ecological: altitudinal distribution and types of vegetation in the locations containing the species. In addition, a comparison of a number of useful species was made through the total number of species reported by Tejero-Díez and Mickel (2004). A centered principal components analysis (PCA) on a correlation matrix was performed to characterize possible groups through ethnicity-species-type of vegetation.

RESULTS

Traditional knowledge and uses among ethnic and mestizo groups.—Fifty useful species and two varieties, distributed in 30 genera and corresponding to 15 families (Table 1), were recorded in the three PTRs. Families with more useful species include Polypodiaceae (11), Pteridaceae (8), and Cyatheaceae (6) (Figure 2A). The most common genera were *Pleopeltis* (4), *Selaginella* (4), and *Cyathea* (3).

The largest number of useful Lycophyta and Polypodiophyta was recorded among Mazatecs (21), Zapotecs (19), and Mixes (19), which is correlated, in part, with the highest number of municipalities represented by each group. The rest of the ethnic groups were represented by three or fewer municipalities, except the Chinantec ethnic group (13), where few species were also reported (Table 1). Two patterns were noted among the useful species: One pattern corresponded to species used by at least four ethnic groups, such as *Equisetum myriochaetum*, *Odontosoria schlechtendalii*, *Lycopodium clavatum*, and *Phlebodium pseudoaureum*. The first three species have a great variety of uses, which change in function depending on the ethnic group. Thus, the common use of *E. myriochaetum* is as a medicinal plant; however, Mixes use it for forage or for veterinary purposes. *Odontosoria schlechtendalii* is a more versatile species: Chinantecs and Zapotecs consider it an ornamental plant, Mixes use it for medicinal purposes, and Cuicatecs include it in magic-religious practices and in handcrafting. *Lycopodium clavatum* and *Phlebodium pseudoaureum* are also versatile species that have three different uses that change depending on the ethnic group (Table 1). The rest of the species are used for only one of the categories considered.

The second usage pattern was identified with species having at least four categories of use, such as *Cyathea fulva* (environmental, medicinal, handcrafting, construction), *Lophosoria quadripinnata* (handcrafting, medicinal, construction, magic-religious), and *Odontosoria schlechtendalii* (handcrafting, magic-religious, ornamental, medicinal). The rest of the species have fewer than four uses, indicating a specialized knowledge of these species inside communities or a specialized role of these species for specific uses (Table 1).

Previous studies reported 627 species for Oaxaca, and at a regional scale, a great number of species was collected in areas inhabited by Zapotecs (Tejero-Díez and Mickel, 2004). Nevertheless, the number of useful species recorded in the present study is low for this and the rest of the ethnic groups. Part of the traditional knowledge refers to the local names of useful species. Of the 50

useful species recorded during the fieldwork, 41 are named. Of these, 21 have both a Spanish name and in one of the languages, 13 are recognized only in some of the languages, and only seven have a common name in Spanish (Figure 2B, Table 1). This means that more than 68% of the species are named in local languages.

Results indicated that the ethnic groups with higher records of useful species reported about 52–68% of them with local names. Even when this relationship was highly variable in the rest of the ethnic groups, a similar pattern of nomenclature was expected if these plants are important and frequently used. In the present study, number of species named in local languages depended on the knowledge of our guides (see methods), who did not remember the local names of some of the species that were collected. Some examples of species named in Spanish and local languages are *Odontosoria schlechtendalii*, which received names in Mixe, Chinanteco, Cuicatec, and Spanish, and *Equisetum myriochaetum*, which received names in Zapotec, Mixe, Mazatec, Nahuatl, and Spanish (Table 1). In some cases, the number of names is not associated with the number of uses; rather, the names represent linguistic variations of one language. *Pityrogramma calomelanos*, for example, has five variations in the Zapotec language, yet it is used only for magic-religious ceremonies. Names also represent regional variations, such as *Cyathea schiedeana* or *Lycopodium clavatum*, which have different Spanish names in different municipalities (Table 1).

Uses are grouped into eight categories: medicinal, ornamental, handcrafting, magic-religious, construction, environmental, forage, and veterinary (Figure 2C), of which medicinal, ornamental, and handcrafting uses are the most important. Medicinal uses are highly variable and include the treatment of kidney aches, as well as coughing, through infusions prepared with species such as *Equisetum myriochaetum* or *Phlebodium pseudoaureum* (Figure 3A). Ornamental uses, which are frequent among species of Polypodiaceae family, include the use of leaves in flower arrangements on altars and live plants grown in pots. (Figure 3B). Handcrafting plants include the fronds of *Pteridium arachnoideum*, which are placed in the bottom of the pot for cooking tamales, and a mixture of the fronds of *Mildella intramarginalis* and *Gleichenella pectinata*, which are placed together as a nest for turkeys or chickens. *Equisetum myriochaetum* is exclusively used for veterinary and forage purposes; in the first case, it is used to deflate the bellies of animals (horses, mules, donkeys, cows, etc.). Plants used for construction include several species of arborescent ferns, such as *Sphaeropteris horrida*, *Cyathea myosuroides*, and *Cyathea fulva*, which are used as rustic posts (“horcones”) or for ceilings. Plants used for magic-religious purposes include species such as *Myriopteris notholaenoides*, *Pityrogramma calomelanos* (Figure 3C), *Adiantum andicola*, and *Hemionitis palmata*, which are used in the preparation of infusions to relieve discomfort caused by psychosomatic conditions like “susto” (panic attacks) and to prevent children from wetting the bed. In the case of *H. palmata* (“susto de perro”), people associate the form

TABLE 1. Useful species of Lycophyta and Polypodiophyta of the state of Oaxaca, including those collected in the present study, those reported only in previous studies ^(a), and those reported in literature and collected in the present study ^(b). Category of use is indicated: EN, environmental; ME, medicinal; C, construction; F, forage; V, veterinary; H, handcraft; O, ornamental; MR, magic-religious. (Number of municipalities inhabited by each ethnic or mestizo group is indicated in parenthesis). Blank spaces indicate no name reported. (chi= chinantec; cu= cuicatec; sp= spanish; ma= mazatec; mi= mixe; na=nahuatl; nd=not available; zo= zoque). Types of vegetation are also indicated: OPF, oak-pine forest; OF, oak forest; PF, pine forest; PTF, perennial tropical forest; SDTF, subdeciduous tropical forest; DTF, deciduous tropical forest; montane cloud forest, MCF; gallery vegetation, GV; submontane scrub, SMS.

Family	Species	Local name	Zoque (2)	Cuicatec (3)	Mixtec (2)
Anemiaceae	<i>Anemia</i> aff. <i>adiantifolia</i> ^a				
Aspleniaceae	<i>Asplenium sessilifolium</i> Desv. (A.s.) <i>Asplenium</i> sp. ^a				
Athyriaceae	<i>Athyrium</i> sp. ^a <i>Diplazium ternatum</i> Liebm (D.t.)		EN		
Blechnaceae	<i>Blechnum appendiculatum</i> Willd. (B.a.) <i>Woodwardia spinulosa</i> M. Martens & Galeotti (W.s.)	ma mi			
Cyatheaceae	<i>Alsophila firma</i> (Baker) D. S. Conant (A.f.) <i>Cyathea divergens</i> Kunze var. <i>tuerckheimii</i> (Maxon) R. M. Tryon (C.d. var t.) <i>Cyathea fulva</i> (M. Martens & galeotti) Fée (C.f.) <i>Cyathea myosuroides</i> (Liebm.) Domin (C.m.) <i>Cyathea schiedeana</i> (C. Presl) Domin (C.schi.) <i>Sphaeropteris horrida</i> ((Liebm.) R. M. Tryon (S.h.)	ma, sp (cola de chango) ma, chi, sp (helecho) sp (helecho arborescente) sp (mano de león, palo cola de chango), za sp (mano de león, helecho), za, mi	ME EN		
Dennstaedtiaceae	<i>Pteridium aquilinum</i> (L.) Kuhn var. <i>feeii</i> (W. Schaffn. ex Fée) Maxon ex Yunck. ^b P.a. var f.) <i>Pteridium arachnoideum</i> (Kaulf.) Maxon (P.a.) <i>Pteridium caudatum</i> (L.) Maxon (P.c.)	 sp (copetate), mi, za mi			
Dicksoniaceae	<i>Lophosoria quadripinnata</i> (J. F. Gmel.) C. Chr. (L.q).	sp (copetate, helecho), ma			
Dryopteridaceae	<i>Dryopteris wallichiana</i> (Spreng.) Hyl. ^b (D.w.) <i>Elaphoglossum ipshookense</i> Mickel ^a <i>Elaphoglossum petiolatum</i> (Sw.) Urb. (E.p.) <i>Elaphoglossum</i> sp. ^a <i>Elaphoglossum sartorii</i> (Liebm.) Mickel (E.s.) <i>Elaphoglossum vestitum</i> (Schltdl. & Cham.) Schott ex T. Moore (E.v.) <i>Polybotrya polybotryoides</i> (Baker) Christ (P.pb.)	sp (cola de caballo, copetate húmedo, copetatillo, helecho), mix sp (perro amarillo), za ma ma sp (helecho, helecho trepador), zo	 EN		H

TABLE 1. Extended.

Mazatec (13)	Nahua (2)	Chinantec (13)	Zapotec (30)	Mixe (16)	Mestizo (4)	Altitude	Type of vegetation
			O			825	MCF
ME						716 1426	PTF, SDTF STDF
				MR		1751	GV
ME						448 - 1175	PTF, SDTF
C, ME						1245	OF
ME		H, C				741 – 2200	OF, PTF, SDTF, MCF
				C		525	OPF
			C			1094-1253	MCF
ME			0	C		1175-1358	PTF, SDTF, MCF
	H			ME		2213-2596	OPF, MCF
			ME	H		1496-1635	PTF, SDTF, OF
H, MR, ME			C	H		1614 1828-2200	OPF OF,PF, MCF
H			O			2200-3020	MCF, OPF
			MR			2000	OPF
ME						1383	PTF, SDTF
ME						1383	PTF, SDTF
						716-741	PTF, SDTF, OF

TABLE 1. Continued.

Family	Species	Local name	Zoque (2)	Cuicatec (3)	Mixtec (2)
Equisetaceae	<i>Equisetum giganteum</i> L. ^a				
	<i>Equisetum hyemale</i> L. var. <i>affine</i> (Engelm.) A. A. Eaton ^b (E.h. var a.)				
	<i>Equisetum</i> sp. ^a				
	<i>Equisetum myriochaetum</i> Schldl. & Cham. (E.m.)	sp (carricillo, cola de caballo), ma, mi, na, za		ME	
Gleicheniaceae	<i>Gleichenella pectinata</i> (Willd.) Ching (G.p.)	sp (copetate), za			
LindPTFeaceae	<i>Odontosoria schlechtendalii</i> (C. Presl) C. Chr. (O.sch.)	sp (musgo delgado, copetatillo), cu, chi, mi		H, MR	
Lycopodiaceae	<i>Diphasiastrum thyoides</i> (Humb. & Bonpl. ex Willd.) Holub ^b (D.thy.)	sp (musgo liso)			
	<i>Lycopodium clavatum</i> L. ^b (L.c.)	sp (cacho de venado, cola de chango), mi	EN		
	<i>Palhinhaea cernua</i> (L.) Vasc. & Franco (P.cer.)	sp (musgo), chi			
	<i>Campyloneurum angustifolium</i> (Sw.) Fée (C.a.)	ma			
Polypodiaceae	<i>Campyloneurum tenuipes</i> Maxon (C.t.)	ma			
	<i>Niphidium crassifolium</i> (L.) Lellinger (N.c.)				
	<i>Pecluma alfredii</i> (Rosenst.) M. G. Price (P.al.)	mi			
	<i>Phlebodium aureum</i> (L.) J. Sm. ^a				
	<i>Phlebodium pseudoaureum</i> (Cav.) Lellinger (P.psa.)	sp (copetate blanco, palmerita), cu, za		ME	
	<i>Pleopeltis collinsii</i> (Maxon) A. R. Sm. & Tejero (P.co.)	mi			
	<i>Pleopeltis crassinervata</i> (Fée) T. Moore ^a				
	<i>Pleopeltis lepidotricha</i> (Fée) A. R. Sm. & Tejero (P.l.)	sp (palmerita)			
	<i>Pleopeltis mexicana</i> (Fée) Mickel & Beitel [= <i>Pleopeltis macrocarpa</i>] ^a				
	<i>Pleopeltis polypodioides</i> (L.) E. G. Andrews & Windham ^b (P.po.)				
	<i>Pleopeltis polypodioides</i> (L.) E. G. Andrews & Windham var. <i>polypodioides</i> (P.po. var po.)				
	<i>Polypodium martensii</i> Mett. (P.m.)	sp (palmerita)			
	<i>Polypodium montigenum</i> Maxon ^a				
	<i>Polypodium plesiosorum</i> Kunze (P.p.)				
	<i>Polypodium</i> sp. ^a				
	<i>Serpocaulon triseriale</i> (Sw.) A. R. Sm. (S.t.)	sp (palmerita), za			
Pteridaceae	<i>Adiantum</i> sp. ^a				
	<i>Adiantum</i> aff. <i>capillus-veneris</i> ^a				
	<i>Adiantum andicola</i> Liebm. (A.a.)	sp (cilantrillo), mi			
	<i>Adiantum concinnum</i> Humb. & Bonpl. ex Willd. (A.c.)	mi			
	<i>Hemionitis palmata</i> L. (H.p.)	sp (susto de perro)			

TABLE 1. Continued, extended.

Mazatec (13)	Nahua (2)	Chinantec (13)	Zapotec (30)	Mixe (16)	Mestizo (4)	Altitude	Type of vegetation
				ME	ME	1305- 2151	DTF-OPF, OPF
ME	ME		ME	F, V, ME	ME	601-2786	DTF, PTF, SDTF, GV, OPF, MCF, OPF
			H			745	MCF
		O	O	ME		1299-1475	MCF, OF
O	O					2076-2164	MCF
H, O			O	O		681-2671	MCF, OF, OPF
		O	O			649-1557	PTF, SDTF, MCF
ME						1426	PTF
ME						1438	PTF, SDTF
			O			695	PTF, SDTF
				O		1606	MCF
ME			ME, O	O	O	1000-2181	PTF, SDTF, MCF, BEP
				O		1614	OPF
					O	2153	BEP
				O		600	PTF, SDTF
ME						1881	MCF
					O	2144	BEP
EN						2200	MCF
			O			1000-1476	MCF, PF
EN				MR, ME		1614-2200	BEP, OPF, MCF
				H		1407	OPF
		MR				99	PTF, SDTF

TABLE 1. Continued.

Family	Species	Local name	Zoque (2)	Cuicatec (3)	Mixtec (2)
Selaginellaceae	<i>Mildella intramarginalis</i> (Kaulf. ex Link) Trevis. (M.i.)	sp (helecho), mi			
	<i>Myriopteris myriophylla</i> (Desv.) J. Sm. ^a				
	<i>Myriopteris notholaenoides</i> (Desv.) Grusz & Windham (M.n.)	sp (helecho de medicina)			
	<i>Notholaena</i> sp. ^a				
	<i>Pellaea cordifolia</i> (Sessé & Moc.) A. R. Sm. ^a				
	<i>Pellaea ovata</i> (Desv.) Weath. ^a				
	<i>Pellaea PTFgittata</i> (Cav.) Link ^a				
	<i>Pellaea</i> sp. ^a				
	<i>Pityrogramma calomelanos</i> (L.) Link (P.cal.)	sp (hierba del susto), za			
	<i>Pityrogramma ebenea</i> (L.) Proctor (P.e.)	sp (hierba del susto), ma, za			
	<i>Pityrogramma trifoliata</i> (L.) R. M. Tryon (P.t.)	sp (helecho)			
	<i>Pteris</i> sp. ^a				
	<i>Selaginella illecebroso</i> Alston (S.i.)				
	<i>Selaginella lepidophylla</i> (Hook. & Grev.) Spring ^a				
	<i>Selaginella pallascens</i> (C. Presl) Spring (S.pall.)	sp (planta del riñón), ma			
	<i>Selaginella porphyrospora</i> A. Braun (S.p.)	mi			
	<i>Selaginella stellata</i> Spring (S.s.)	chi, mi, za			
	<i>Selaginella</i> sp. ^a				
Thelypteridaceae	<i>Goniopteris imbricata</i> (Liebm.) Á. Löve & D. Löve (G.i.)	chi			
	<i>Macrothelypteris torresiana</i> (Gaudich.) Ching ^a				
	<i>Thelypteris puberula</i> (Baker) C. V. Morton ^a				

of the tender frond with dog paws, and they use it to cure the panic attack produced by a growling dog (Figure 3D).

Plants used for environmental purposes include *Diplazium ternatum*, *Polybotrya polybotryoides*, *Dryopteris wallichiana*, and *Polypodium plesiosorum*, species that people consider important because they are beautiful in their natural habitats; people even occasionally propagate them in their yards.

Seventy-four percent of species (37) have a single use only. *Cyathea fulva*, *Lophosoria quadripinnata*, and *Odontosoria schlechtendalii* have four uses, although they share handcrafting and medicinal uses (Figure 2D, Table 1).

Ethnic group distribution, altitudinal distribution of species, and type of vegetation.—Eighty percent of species (40) were collected above 1,000 m, growing in nine types of vegetation, mainly in montane cloud forests. Only 10 species were collected under 1,000 m asl from among four types of vegetation, mainly in subdeciduous and perennial tropical forests.

TABLE 1. Continued, extended.

Mazatec (13)	Nahua (2)	Chinantec (13)	Zapotec (30)	Mixe (16)	Mestizo (4)	Altitude	Type of vegetation
				H		912	OPF
MR						1911	MCF
			MR			649-1042	PTF, SDTF, OF, PF
ME			MR			1564-1880	GV, PTF, SDTF
			ME			1459	SMS
		O				463	PTF, SDTF
ME						1922	PTF, SDTF
				O		1558	MCF
		ME	O	O		843-1558	MCF
		ME				581	PTF, SDTF

A vegetation analysis revealed that montane cloud forests contain the highest number (22) of useful species collected (681 at 2,671 m asl) (Figure 4), followed by subdeciduous and perennial tropical forests (20 species each, from 99 m asl to 1,922 m asl). Twelve species were collected in oak-pine forest (Table 1).

Even where the data are not conclusive, it is important to note that some species are distributed along the area of study and are present among a variety of types of vegetation, such as *Equisetum myriochaetum*, which was found among seven types of vegetation between 601 and 2,786 m asl: *Cyathea fulva*, *Lophosoria quadripinnata*, *Equisetum hyemale*, *Lycopodium clavatum*, *Palhinhaea cernua*, *Phlebodium pseudoaureum*, *Adiantum andicola*, and *Pityrogramma calomelanos*, which were collected from among at least three types of vegetation. Other species were collected only from among one type of vegetation, such as *Myriopteris notholaenoides* and *Pityrogramma trifoliata* (Table 1).

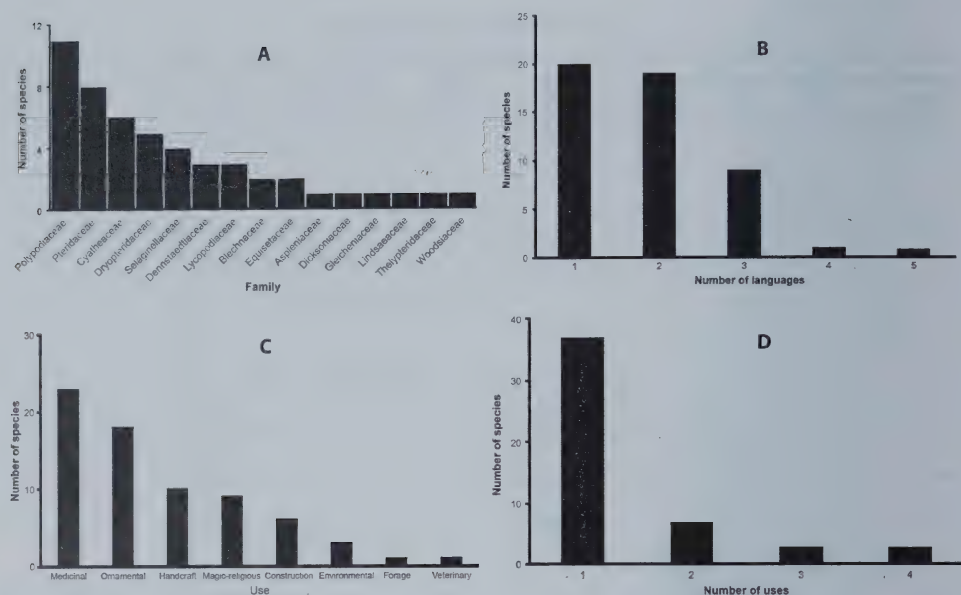


FIG. 2. 2A) Fifteen most important botanical families of Lycophyta and Polypodiophyta in the state of Oaxaca; 2B) Number of useful species receiving names in indigenous languages; 2C) Number of useful species within each category of use of Lycophyta and Polypodiophyta; 2D) Number of useful species with different number of uses.

Some species were associated with one type of vegetation and one ethnic group; among Mixes, all useful species come from oak-pine forest (525 to 2,000 m asl): *Cyathea myosuroides*, *Pteridium caudatum*, *Elaphoglossum petiolatum*, *Pleopeltis collinsii*, *Adiantum concinnum*, and *Mildella intramarginalis*. Other species growing exclusively in subdeciduous and perennial tropical forests (99 to 1,922 m asl), are associated with different ethnic groups, such as *Diplazium ternatum*, *Alsophila firma* (Zoque, and Mazatec); *Elaphoglossum sartorii*, *Elaphoglossum vestitum*, *Campyloneurum tenuipes*, and *Selaginella pallescens* (Mazatec); *Hemionitis palmata*, *Selaginella illecebrosa*, *Goniopteris imbricata* (Chinantec); *Niphidium crassifolium* (Zapotec), and *Pleopeltis polypodioides* (Mixe). The remaining species do not present any kind of association, either with a particular ethnicity or type of vegetation. Multivariate analysis exhibits this weak grouping (Figure 4). The first two axes of PCA explained only 26.4% of the variance, exhibiting a weak grouping. The first axis shows no grouping pattern. Meanwhile, the second axis shows species groupings distributed in the highlands—in which many species were collected only in montane cloud forest and oak-pine forest or only in oak forest (upper section)—as well as other subgroups, which correspond to species from lowland deciduous tropical forests, subdeciduous tropical forests, or perennial tropical forests. Associations with some ethnicities were also identified. Nevertheless, these

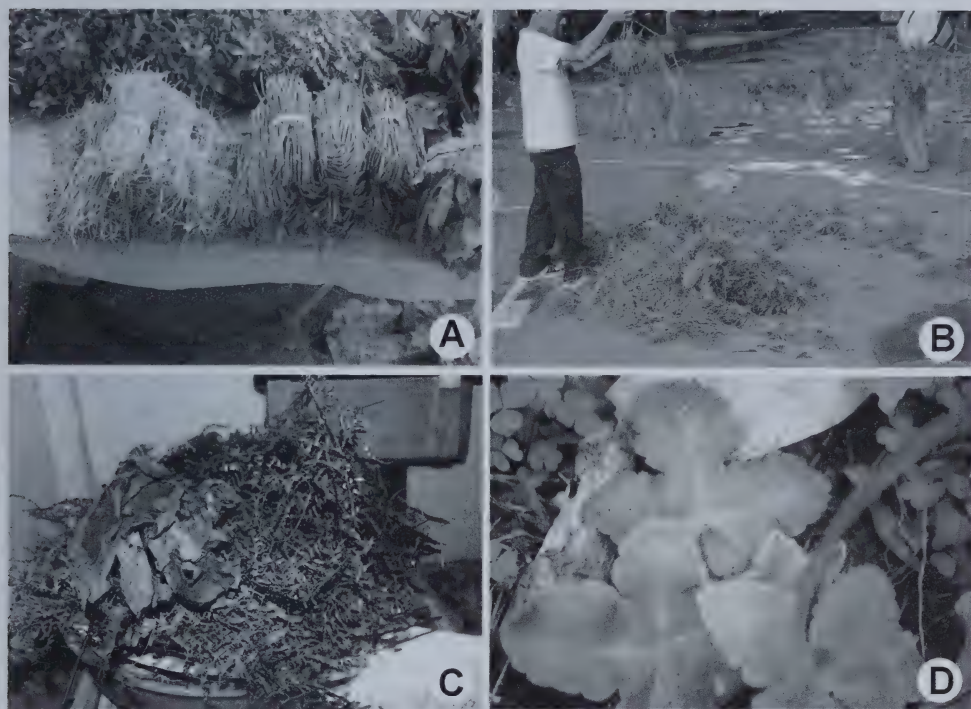


FIG. 3. Some examples of useful Lycophyta and Polypodiophyta: 3A) small packages of *Equisetum hyemale* in a local market; 3B) long strips of *Diphasiastrum thyoides* and *Lycopodium clavatum* forming an arch in the front door of a municipality building in Eloxochitlán de Flores Magón, Oaxaca; 3C) dry structures of *Pityrogramma calomelanos* ready to boil for medicine infusions; 3D) live individuals of *Hemionitis palmata*, which fronds are associated with bearing dog, used for “dog scare”.

groups are represented by only a few species. The rest of them do not exhibit any pattern (For acronyms, check Table 1).

DISCUSSION

Traditional knowledge and uses of Lycophyta and Polypodiophyta in the state of Oaxaca are dynamic, transmitted vertically and horizontally within communities, and used to meet different needs, including curing of somatic or psychosomatic illness, commemoration of events (house altars or temples), rustic construction, and handcrafting. The number of useful species recorded in this study area represents only 8% of the total number of species for the state of Oaxaca (50 of 627) (Tejero-Díez and Mickel, 2004). However, the number of genera recorded in this study represents 25% of the total for the Oaxaca state (112). Data obtained in the present study suggest that inhabitants of three ethnic groups—Mazatecs, Zapotecs, and Mixes—use most of the ferns in Oaxaca. However, this pattern is not definitive because previous records have reported uses by Cuicatecs (Solis-Rojas, 2006; Mercado-González, 2013),

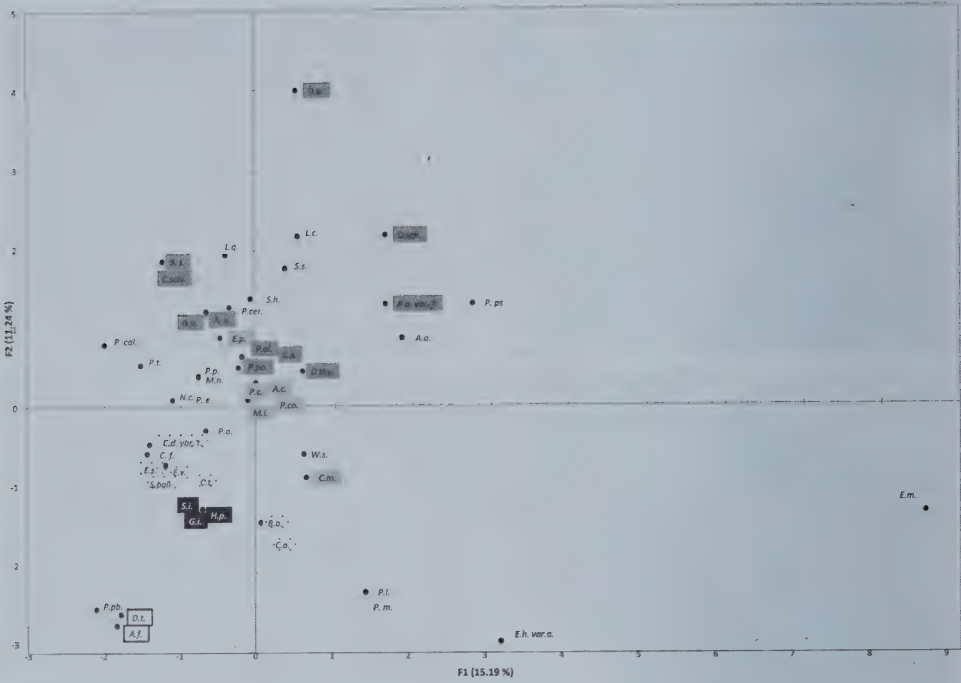


FIG. 4. Principal Components Analysis (PCA) on correlation matrix, for ethnic group-type of vegetation-altitude: dark gray, species distributed only in montane cloud forest; light gray, species associated only with mixes, and distributed only in oak-pine forest; white square, species associated only with zoques and mazatecs; square dotted, species associated only with mazatecs, coming from tropical vegetation; black square, species associated only with chinantecs. These species are growing exclusively in subdeciduous and perennial tropical forest (99 to 1922 m asl).

Triquis, and Mixtecs (Solano-Vargas, 2008), although the latter research did not specify which species were useful or the ethnic groups among which different species were used. Additional information from the literature indicates that at least 82 species of ferns and lycophytes are used in the state of Oaxaca (Table 1). It also emphasizes the fact that although previous studies reporting on these species have been published since 2006, they cover only three municipalities of Oaxaca and give no particular attention to this group of plants. In this regard, our work contributes information on 61% of the useful species in Oaxaca. This suggests that ethnobotanical exploration is still required to register plant diversity and traditional knowledge and uses of plants among different ethnic groups. It is important to point out that all species reported in this work do not represent all of those mentioned by the local guides during the fieldwork; this was because several species were not collected due to seasonal limitations affecting their developmental maturity. Therefore, our list of ferns could increase significantly. Our regional approach enables us to demonstrate that although there is traditional knowledge

regarding this group of plants, their uses, and their cultural value vary among ethnic groups.

Contrasting ethnobotanical information of the present survey with previous studies at a national or world level (Murillo, 1983; Muñoz-Díaz de León *et al.*, 2007; Navarrete *et al.*, 2006, Singh and Khare 2011; Barku, Opoku-Boahen and Dali, 2014; Bellia and Pieroni, 2015) reveals that this is the first ethnobotanical study that analyzes the traditional uses of these taxonomic groups within different ethnic groups inside a geographic area (i.e., Oaxaca). In addition, our study contributes new records of useful species, as well as different categories of use, including handcrafting, veterinary, and environmental uses. Previous studies have analyzed some species from an ecological perspective, such as *Pteridium caudatum* and *Pteridium aquilinum* (Pakeman *et al.*, 2011; Barkatullah, *et al.*, 2012, Pollio *et al.*, 2016). Nevertheless, pharmacological approaches based on traditional medicinal use are the main focus of extensive literature about *Equisetum hyemale* (Ferrazzano *et al.*, 2013; Goswami *et al.*, 2016; Pollio *et al.*, 2016), *Lycopodium clavatum* (Upreti and Gyawali, 2015; Goswami *et al.*, 2016), *Phlebodium pseudoaureum* (Leal *et al.*, 2014), and *Pityrogramma calomelanos* (Lans, 2006; Luciano-Montalvo *et al.*, 2013). Despite the relevance of these studies, the local value of these species must be taken into account and understood within the context of each ethnic group's cosmovision to preserve traditional uses and to promote the sustainable management of not only plant populations but also the plant communities from which they are gathered.

Another aspect of our study relates to the folk taxonomy of these species. Even when local names are not described here due to the linguistic limitations of the authors, it is noteworthy that 64% of species were named in at least one of the eight local languages, some of them with at least two linguistic variants. Such an observation reinforces the argument that people of local communities recognize and codify the diversity of life and that classification systems are very diverse and complex. Even within an ethnic group, regional variations emphasize the complexity of classification (de Avila 2010).

A preferential distribution of useful Lycophyta and Polypodiophyta in montane cloud forests and temperate forests (i.e., pine, oak, oak-pine; almost 30% of collected species), demonstrates that this group of plants is associated with temperate climates and wet environments (Tejero-Díez and Mickel, 2004). Indeed, the montane cloud, oak, and oak-pine forests contain the highest percentages of Lycophyta and Polypodiophyta (20%, 16%, and 14%, respectively; Tejero-Díez and Mickel, 2004). This pattern is also observed at the level of the districts of Teotitlán, Mixe, and Ixtlán, which have areas on the windward side of the Sierra Madre de Oaxaca exposed to humid winds most of the year, coming from the Gulf of Mexico (Tejero-Díez and Mickel, 2004). Those districts contained the highest number of taxa previously collected.

Montane cloud forests have larger areas of distribution in Oaxaca (Torres-Collin, 2004) and contain some of the most important types of vegetation that provide useful plant resources to local people (Rendón-Aguilar *et al.*, 2017). The correlation between higher areas of biological diversity and the presence

of ethnic groups has been analyzed in previous research and is here demonstrated again, facilitating the maintenance and reinforcement of the traditional knowledge and uses of natural resources.

CONCLUSIONS

In the study area of the state of Oaxaca, 50 species of Lycophyta and Polypodiophyta were found, with eight categories of use, including medicinal, ornamental, and handcrafting uses.

The use of these taxa is widespread in the studied communities in Oaxaca. However, the greatest number of species was recorded among Mazatecs, Zapotecs, and Mixes. Regarding the useful species, there are two conditions: The first is related to species used among at least four ethnic groups, the number of uses for which varies from two to four—such as *Equisetum myriochaetum*, *Odontosoria schlechtendalii*, *Lycopodium clavatum*, and *Phlebodium pseudoaureum*—the other related by species with at least four categories of use, such as *Cyathea fulva*, *Lophosoria quadripinnata*, and *Odontosoria schlechtendalii*, used by few ethnic groups. The rest are used in one or a few communities and have less than four uses, indicating a specialized knowledge of these species inside communities and/or a specialized role of these species for specific uses. More than half of the species are named in at least one language, which reinforces the fact that species are recognized, valued, and important in people's daily lives and in their world view.

It is noteworthy that more than one third of the species identified come from montane cloud forests, revealing the great importance of this type of community in the provision of plant resources for indigenous communities, as well as the importance of montane forests in providing one of the most useful types of vegetation in Oaxaca (Torres-Collin, 2004). It is important to note that the use of plants in ethnic communities in Oaxaca and the country is a current, valid, and dynamic reality. Revealing this ancient knowledge should be a starting point for new forms of perception and use of nature. Nevertheless, owing to methodological limitations, many useful Lycophyta and Pteridophyta species were omitted from the present research. We anticipate, however, that future visits to these localities will add to the records of these plants. In the context of the world and national publications covering the ethnobotanical aspects of Polypodiophyta and Lycopodiophyta, our research adds records of useful species within these taxonomic groups, and it is the first study to analyze their uses in the context of ethnic groups inside a geographic area (the state of Oaxaca).

ACKNOWLEDGEMENTS

Authors want to thank to the Municipal authorities, as well as Ejidal and Communal Lands of the 85 municipalities that were visited during the development of the project; also, to local guides to help us during the fieldwork. This project was developed through the financial supporting of the

CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad), through the project "Inventario Etnoflorístico en regiones oaxaqueñas con gran diversidad" (JF102). We also want to thank Universidad Autónoma Metropolitana Iztapalapa for the logistic support. During the development of the project many undergraduate students incorporate to the project through social services or research seminars: Rubén David Maqueda Valdez, Alejandro Suárez Camargo, Brian Giovanni Martínez Bautista, and Mario Merino Martínez. Jorge Santana Carrillo, Technician of the Metropolitan herbarium in Mexico City (UAMIZ Metropolitan herbarium) participated during fieldwork, and during review of specimens in the laboratory. Thanks to M. en B. Alma Delia Toledo Guzmán, who elaborated the map, and to M. en B. Monserrat Jiménez for figures edition. Paulina Rendón Aguilar reviewed the first English version, and Dra. Rosa Cerro Tlalilpa reviewed the final English version and made important comments.

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A Contribution Toward the Knowledge of Ferns and Lycophytes from Northern and Northwestern Myanmar

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ABSTRACT.—Although the montane forests of northern Myanmar are part of one of the most biodiverse areas of the world, our knowledge of species richness and elevational distribution of species within these forests is poor and scattered at both spatial and temporal scales. Over the last five decades, very few floristic assessments have been undertaken. This is especially true for ferns and lycophytes. An international collaborative project team undertook the first plot-based inventory of vascular plant species' elevational distribution in northern and northwestern Myanmar in 2012, 2013 and 2014. At elevational gradients in northern and north-western Myanmar, four 400 m² plots were sampled at intervals of 200 m in natural or little-disturbed forests and alpine thickets. We recorded all ferns and lycophytes from 132 plots, producing a total of 3,978 specimens. Based on these collections we present a list of fern and lycophyte species. A total of 299 species from 72 genera and 24 families were identified. This pilot project is a contribution to the upcoming Flora of Myanmar and provides a baseline dataset of the region to set priorities for conservation and the gazettement of protected areas.

KEY WORDS.—elevational transects; flora; pilot project; plot-based; species distribution pattern

Indo-Burma is one of the biodiversity hotspots highlighted by Myers *et al.* (2000), and the northern area of Myanmar covered by this study lies at the

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junction of three floristic regions: Sino-Himalayan, Indo-Chinese and India (Miehe, Pendry, and Chaudhary, 2015). It is located between the eastern Himalaya and the mountains of Southwest China and is a region of great species richness, with 4,000–5,000 species of vascular plants per 10,000 km² (Barthlott *et al.*, 2007; Zhao *et al.*, 2016). However, the flora, vegetation and species distribution patterns are almost unknown. In contrast to most Himalayan countries, Myanmar lacks a national flora and thus a thorough floristic assessment (Frodin, 2001).

The earliest floristic accounts from Myanmar were produced when Myanmar was part of British India. These were published in the late 19th century and focused primarily on the timber resources. The most comprehensive of these early publications was Kurz's 'Forest Flora of British Burma' (Kurz, 1877) which included about 2,000 woody plant species. Its focus was to produce an inventory of forest trees, but it did include a few herbaceous plants and the first fern records for Myanmar: species of *Cyathea*, *Alsophila* and *Brainea insignis* (Hook.) J.Sm.. Kurz's original work was updated and republished by Lace (1915), Fischer (1926), Nath Nair (1960) and Hundley and Ko (1987). The most recent checklist (Kress *et al.*, 2003), primarily derived from these earlier works, includes 11,800 taxa but does not include ferns and lycophytes. The field work for the collections that underpinned these checklists was carried out mostly in western and southern Myanmar. The floristic knowledge of upper Myanmar and especially northern Myanmar is, consequently, much more limited.

The collections of Frank Kingdon-Ward from 1938/39 were published by Merrill (1941) with nine fern species from the Vernay-Cutting expedition. Frederick Dickason compiled his collection of 325 fern species during the period from 1930 to 1942 from the southern Tanintharyi coastline, Chin State, and the Shan Plateau, including a limited number of collections made by Harold Young from northern Myanmar up to the Assam-Burma border in 1943 (Dickason, 1946). The most up-to-date and comprehensive list of ferns was published by Dickason (1946) with 460 species belonging to 104 genera. He continued collecting until 1970 in Myitkyina, eastern and southern Shan State, Bago, Yangon (Rangoon), and Myeik (collections deposited in Yangon University herbarium RANG). In 1953, P.S. Bell published 46 species of the wild and cultivated "ferns and fern allies" from Yangon-Insein Region, contributing 15 new ferns and 4 new lycophytes to the existing national list. Since then the only reports on collections of ferns from Myanmar are Nwe (2009), Nwe *et al.* (2016) and Thet (2003). At a regional level, fern collections have been published for Yunnan (Kato *et al.*, 1992), for parts of the central Himalaya of Nepal (Iwatsuki, 1988; Miehe, 1990; Fraser-Jenkins, Kandel and Pariyar, 2015; Rajhandary in Miehe, Pendry, and Chaudhary, 2015), for Bhutan (Fraser-Jenkins, Matsumoto, and Wangdi, 2009), for India (Fraser-Jenkins *et al.*, 2016), and in a work mainly on India but also including some records from Nepal and Bhutan (Fraser-Jenkins, 2008).

A reason for the striking contrast between northern Myanmar being a potential center of species diversity due to its locality as a transition between

two floristic realms, yet being very poorly known floristically, may be due to the remoteness and the relatively unstable political situation in this region. However, the recent opening of Myanmar and the receptiveness of the political administration to nature conservation offered a unique possibility to launch an inventory and systematic assessment of the plant diversity of this mountainous region. With this paper, we present, as a first step, a contribution towards the “Pteridophyte checklist of Myanmar” (Fraser-Jenkins and Khine in prep.) and upcoming “Flora of Myanmar”. This is a preliminary checklist in the suspected most species-rich part of the country, part of the “East Himalayas-Yunnan Biodiversity Hotspot”. We present basic data on elevational ranges, frequencies, and life forms of ferns, together with a first outline on richness distribution patterns. The results will be compared to our current knowledge on fern and lycophyte occurrence and distribution patterns worldwide.

MATERIAL AND METHODS

Study areas.—Fern collections were made along elevational gradients in two areas in order to cover diverse altitudinal vegetation zones and thus habitat heterogeneity. In 2012 we sampled an elevational gradient on Natma Taung/Mt. Victoria, Chin State (3,062 m, 21°22'N, 93°90'E, study gradient 400 m to 3000 m) and in both 2013 and 2014 we collected the second gradient in two adjoining areas NW of Putao in Kachin State (Hponyinrazi 4,057 m, 27°56'N, 96°96'E, and Hponkanrazi 3,603 m; 27°50'N, 96°93'E, study gradient 400 m to 4000 m) (Fig. 1). As these mountainous areas are characterized by frequent land-slides, and the topography is very rugged with narrow ridges, some parts of the Hponyinrazi transect is covered by abundant azonal vegetation, disrupting the possibility of a continuous line of plots in virgin and zonal forests. These gaps were, therefore, sampled from the adjacent mountain, Hponkanrazi. The maps were produced based on CHELSA datasets (Karger *et al.*, 2016). Field work was undertaken during the post-monsoon season (October to December) in each year. The northwestern transect, Natma Taung, stretched between 400 m in tropical Southeast Asian Dipterocarp lowland forest to temperate evergreen broadleaved Himalayan *Quercus semecarpifolia*-*Rhododendron arboreum* forest on the summit area of Mt. Victoria (3,003 m). The northern area covered a transect from the intramontane basin of near Putao at 490 m, with *Castanopsis*-Dipterocarp forest, up to the treeline ecotone along with Himalayan bamboo thickets and scattered *Abies delavayi* at 3600 m (Hponkanrazi) and alpine *Rhododendron* dwarf scrub at 4,057 m (Hponyinrazi). Both areas are at least partly under the nature conservation administration of the Forest Department, Ministry of Natural Resources and Environmental Conservation. The forests below 2,000 m in the Natma Taung area and below 1,000 m in northern Myanmar are partly managed by a slash and burn agriculture system known as “Taungya”. However, in both areas the forests were relatively well preserved compared to other Himalayan forests. Whereas forest fires during the dry season may occur in the cloud forests of Natma Taung above 2,000 m, maintaining a savannah-like structure between

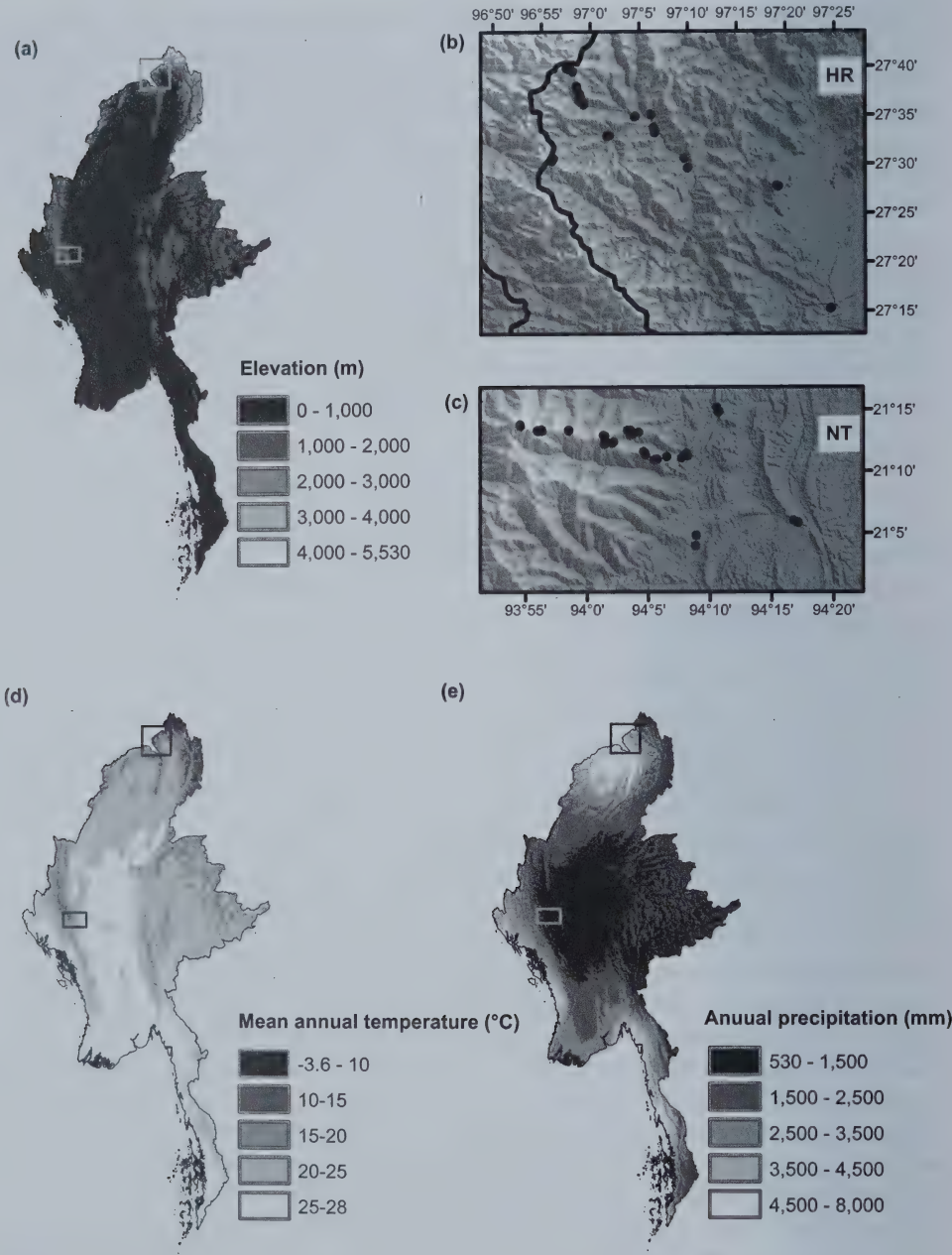


FIG. 1. (a) Elevational pattern of Myanmar as a whole and with close-ups for both elevational gradients; (b) the northern transect, HR (Hponkanrazi + Hponyinrazi), and (c) the northwestern transect, NT (Natma Taung). Within each close-up, the black dots are the sites of the plots that were sampled over elevational distances of about 200 m. (d) Mean annual temperature and (e) annual precipitation from CHELSA datasets.

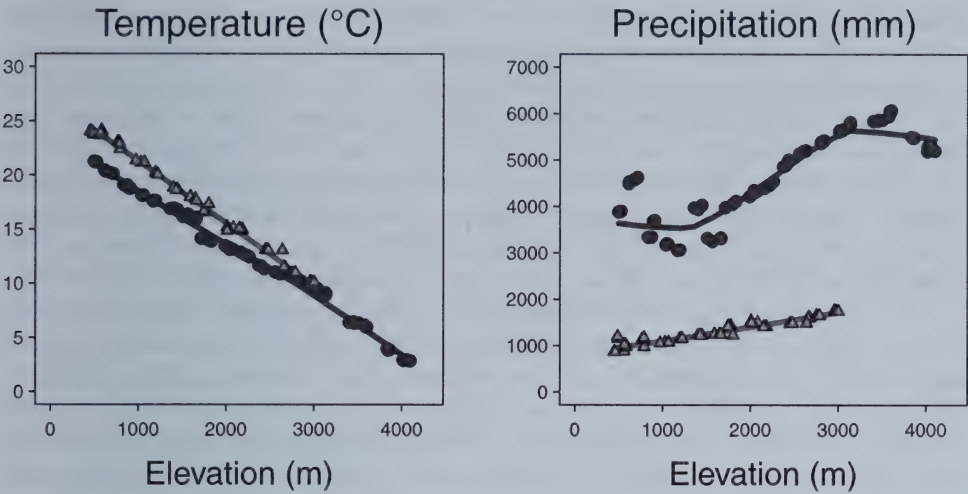


FIG. 2. Patterns of mean annual temperature (left) and annual precipitation (right) along elevational gradients at Natma Taung (NT; grey lines, triangles) and Hponkanrazi + Hponyinrazi (HR; black lines, circles).

forest patches and grassland, the forests of the northern area are untouched above 1,000 m and only lightly used for the collecting of medicinal plants or for hunting. The forest structure and the height of the canopy is however not homogenous, but mirrors succession stages after rockfall or landslides. Bamboo thickets cover wide areas of those mostly very steep slopes.

Both areas merge from the Indo-Chinese Floristic Region of the Palaeotropical Floristic Realm into the Sino-Himalayan Floristic Region of the Holarctic Floristic Realm (Miehe, Pendry, and Chaudhary, 2015). The transition between the tropical Southeast Asian Dipterocarp forests and the temperate evergreen-broadleaved Himalayan Magnolia-Oak forests stretches between 1,500 m and 2,000 m. The summit area of Mt. Victoria, with its open grasslands and Himalayan oak forests, has attracted the attention of botanists and ornithologists since colonial times due to records of Himalayan species isolated from the Himalayan arc by a distance of 900 km (Stresemann and Heinrich, 1939, Kingdon Ward, 1959).

Climate.—Myanmar experiences the Asian Summer monsoon, and most parts of the country receive South-West monsoon rains from May to October (Sein *et al.*, 2015). A long period of seasonal drought with a rapid rise of temperature starts right after the monsoon period, especially in the central basins, while other parts of the country receive rainfall throughout the year, mostly in the lowlands along coastlines and at high elevations. Mountains in Chin State and Northern Myanmar are the orographic barriers for monsoon and the highest rainfall occurs between June and September. Annual precipitation amounts vary from 500 mm in the Central Dry Zone, 2,300 mm in the Chin Hills (gradient Natma Taung), and about 4,000 mm (Thet, 2003) in northern Myanmar (gradient Hponyinrazi / Hponkanrazi, Fig. 2). The northwestern

area, located at the margin of the country's dry zone, receives 1,300 mm annual rainfall at the foot of the slope at 400 m, and 2,300 mm at 3,000 m. The amount of fog precipitation has not been measured, but abundant epiphytic mosses and lichens show that evapotranspiration is hampered due to mountain fog during the rainy season and for most of the year at elevations above 2,000 m. In the north, annual rainfall of more than 4,000 mm has been recorded in the center of an intramontane basin (Putao) at 450 m asl. The CHELSA datasets provide extrapolations of decreasing rainfall with altitude; however the humidity conditions as mirrored by the bryophyte coverage in the tree canopy (Karger *et al.*, 2012) suggest that rainfall increases considerably with altitude. Fog is an important ecological factor, reducing evapotranspiration and reducing the effects of the dry season. The slopes of Hponyinrazi / Hponkanrazi are possibly the wettest slopes in the whole of the Himalayan arc (Miehe *et al.*, 2001). Both areas have cold-air ponding effects with night fog in their intramontane basins at the foot of the slopes; at 1,200 m night frosts regularly occur. Snowfall in the summit area of Mt. Victoria occurs, but is rare, whereas the upper montane *Abies* forests and alpine shrubberies above 3,000 m remain snow-covered between October and May. In total, the Natma Taung gradient is warmer and dryer at same elevations compared to Hponyinrazi / Hponkanrazi (Fig. 2).

Vegetation records.—We used a plot size of 400 m², which is small enough to keep environmental factors and forest structure more or less homogeneous within the plots, and is the minimum area required for representative fern and lycophyte surveys in humid tropical forests (Kessler and Bach, 1999). The plots were usually square (20 m x 20 m) or rectangular (10 m x 40 m) in special relief situations. The minimum distance between the plots was kept to at least 20 m to ensure each plot is independent of the others. The plots were placed at every 200 m of elevation, with four plots established at every elevational level. The plots were located in areas that showed the least possible anthropogenic disturbance. The vegetation sampling was conducted in zonal forest. Extraordinarily wet sites near running water in deep valleys, and frequently disturbed steep slopes and ridges, were not selected to avoid unrepresentative contributions of azonal vegetation. In total we studied 132 vegetation plots, 56 plots at Natma Taung in 14 elevational steps, and 76 plots at Hponkanrazi / Hponyinrazi in 19 elevational steps.

All species were recorded with their substrate and abundance. Discrete clumps of long-creeping rhizomatous plants were assigned as single individuals. Substrates were noted as terrestrial (soil, rocks, and dead wood) and epiphytic. The microhabitat on a tree was recorded for epiphytes, ranging from low trunk (<2 m), high trunk up to first ramification of tree, lower canopy, inner crown, and outer crown (i.e., 'Johansson's zones', Johansson, 1974). Canopy species were checked with binoculars to record individual numbers. Collection and sampling of upper canopy epiphytes on trees up to 50 m tall was done by botanically trained local tree climbers. Additionally, we searched for recently fallen trees and branches inside or in close proximity to the plots for trunk and canopy epiphytes. We also recorded the fertility status

of each species. Three sets of specimen vouchers were collected for all putative species at each elevational step, hence 3,978 vouchers in total.

Plant determination and data analysis.—The determination of the specimens was undertaken by the authors and by taxonomists thanked in the acknowledgements. The species list follows the nomenclature of PPG I (2016), though this does not imply that the taxonomy put forward in that paper is accepted by all authors, notably by CRFJ. The specimens are deposited in the Forest Research Institute herbarium (RAF) in Yezin, Myanmar; Naturalis Biodiversity Center (L) in Leiden, the Netherlands; the Project Herbarium of the Faculty of Geography, Philipps University of Marburg (PHMR) in Germany; Singapore Botanic Gardens (SING) in Singapore; the University of Bonn (BONN) in Germany and the University and Jepson herbaria (UC) in Berkeley, the United States of America. Two transects from northern Myanmar, the Hponkanrazi and Hponyinrazi transects were combined as one elevational gradient and cited as “HR” for simplicity. The Natma Taung transect will be described as “NT” from now onward. The highest and lowest elevations of each species’ occurrence, their locality and abundance, as well as their life form, are also included as part of the species list. The total number of species, as well as the number of epiphytic and terrestrial species, was plotted against the elevation to visualize the species richness pattern along the elevational gradient.

RESULTS AND DISCUSSION

Taxonomic composition.—In 132 survey plots from both transects (56 plots in NT, and 76 plots in HR) 299 species belonging to 72 genera and 24 families were recorded (TABLE 1). Polypodiaceae was the most species-rich family (81 species, 27% of the species recorded) followed by Dryopteridaceae (47 species, 15.7%) and Athyriaceae (32 species, 10.7%). This pattern strikingly coincides with family-level species lists from other regions worldwide. For example, in Costa Rica, one of the global ‘fern hot spots’ (Kreft *et al.*, 2010), with a similar number of plots along an elevational gradient, almost 21% of the species recorded belonged to Polypodiaceae (incl. Grammitidaceae), and about 20% Dryopteridaceae (incl. *Elaphoglossum*) (Kluge and Kessler, 2005). The same picture emerged in a study in Indonesia (Kessler, Kluge, Karger, unpublished data) and Borneo (Kessler, Parris, and Kessler, 2001). However, the most species rich family in the South American Bolivian Andes is Dryopteridaceae at 27%, followed by Polypodiaceae at 18% of the total (Kessler, 2001). A regional study from Nepal has listed Dryopteridaceae and Athyriaceae as the most species-rich families (Bhattarai, Vetaas, and Grytnes, 2004). The similarity of the percentage contribution of the families in species lists may be attributed to the fact that ferns in general are more widespread than seed plants, mainly because of their greater age and thus a longer dispersal period (but see Schneider *et al.*, 2004) and/or because of a higher dispersability (small size of diaspores) and thus because of a high chance of long distance dispersal (Smith, 1972; Kramer, 1993).

TABLE 1. List of species found within this study with data on elevational range, substrates occupied and herbaria. Family order follows PPG1 (2016), within each family, genera and species are listed alphabetically. Species not listed for Myanmar in Dickason (1946) (excluding lycophytes that were not included in that work), Nwe *et al.* (2016) and Indian pteridophytes checklist in Fraser-Jenkins *et al.* (2016) are marked with *. Abbreviations for transects are NT= Natma Taung, HK= Hponkanrazi and HY= Hponyinrazi (both latter combined = HR). The substrate is abbreviated as ground (g), dead wood (w), rock (r), tree trunk below 2 m (t1), 2m to first ramification of the tree (t2), lower crown (t3), inner crown (t4) and outer crown (t5). Collection numbers (ID) and the herbarium where the voucher is deposited is given as b=BONN, l=L, p=PMHR, s=SING, u=UC.

	Transect	Elevation range (m)	Substrate	ID & herbaria
Lycopodiaceae				
<i>Huperzia</i> <i>bucahwangensis</i> Ching	HY	2400–3016	t1,t2	13-070-050 ^s , 13-072-054 ^p , 13-075-002 ^p , 13-076-093 ^p , 13-080-111 ^p
<i>Huperzia delavayi</i> (Christ & Herter) Ching*	HY	3840–3840	g	13-057-025 ^u
<i>Huperzia herteriana</i> (Kümmerle) T.Sen & U.Sen	NT&HY	1593–2839	t1,t2,t3,t4	12-012-001 ^u , 13-073-010 ^p , 13-073-011 ^s , 13-075-011 ^s
<i>Huperzia javanica</i> (Sw.) Fraser-Jenk.	HY	1988–2400	g	13-080-112 ^p , 13-090-001 ^s
<i>Phlegmariurus fordii</i> (Baker) Ching*	NT	1595–1803	t1,t2,t4	12-051-001 ^u , 12-096-026 ^s
<i>Phlegmariurus hamiltonii</i> (Spreng.) Á.Löve & D.Löve	NT, HK&HY	1051–2607	t1,t2,t3,t4	12-012-002 ^s , 12-074-003 ^s , 12-095-028 ^s , 13-077-102 ^p , 13-079-083 ^p , 13-084-022 ^p , 13-086-020 ^p , 13-089-114 ^s , 13-106-012 ^s , 14-032-017 ^s , 14-050-001 ^u
<i>Phlegmariurus phlegmaria</i> (L.) Holub	HK&HY	892–1168	w,t1,t4,t5	13-098-256 ^p , 14-054-020 ^u , 14-055-009 ^s , 14-060-002 ^u
<i>Phlegmariurus pulcherrimus</i> (Wall. ex Hook. & Grev.) Á.Löve & D.Löve*	HK&HY	833–2029	r,t1,t3,t4,t5	13-089-113 ^p , 13-094-146 ^p , 13-095-125 ^s , 13-098-233 ^p , 13-099-020 ^p , 13-106-024 ^p , 14-031-028 ^s , 14-041-008 ^u , 14-042-005 ^u , 14-047-019 ^u , 14-057-011 ^u
<i>Phlegmariurus squarrosus</i> (G.Forst.) Á.Löve & D.Löve*	HK&HY	621–1048	t1,t4	13-105-019 ^s , 14-054-021 ^u , 14-069-002 ^u
<i>Spinulum annotinum</i> (L.) A.Haines*	HK	3588–3588	g	14-026-001 ^s
Selaginellaceae				
<i>Selaginella biformis</i> A.Braun ex Kuhn	HK	1508–1665	g	14-032-010 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Selaginella braunii</i> Baker*	NT	564–1031	g	12-082-060 ^u , 12-082-063 ^u , 12-082-064 ^u , 12-087-001 ^u
<i>Selaginella chrysocaulos</i> (Hook. & Grev.) Spring	NT	2011–2011	r,t1	12-074-005 ^s
<i>Selaginella doederleinii</i> Hieron. *	HY	1447–2162	g,t1	13-086-017 ^s , 13-088-034 ^u , 13-089-112 ^u , 14-048-011 ^s
<i>Selaginella helferi</i> Warb.	HY	1036–1177	g,w	13-098-240 ^p , 13-101-289 ^p , 13-102-264 ^s , 13-103-245 ^p , 13-104-003 ^s , 14-054-027 ^s
<i>Selaginella involvens</i> (Sw.) Spring	NT&HY	1492–2162	g,w,r,t1,t2	12-046-005 ^u , 12-048-012 ^s , 12-074-006 ^u , 12-077-005 ^u , 13-086-012 ^s , 13-088-044 ^s
<i>Selaginella minutifolia</i> Spring	NT	790–790	g,r	12-016-002 ^s
<i>Selaginella monospora</i> Spring	HY	2011–2807	g,r,t1	13-074-071 ^p , 13-076-082 ^s , 13-076-083 ^p , 13-077-091 ^s , 13-078-012 ^p , 13-080-104 ^p , 13-085-112 ^p
<i>Selaginella picta</i> A.Braun ex Baker	HK	614–715	g	14-066-237 ^s , 14-067-146 ^s
<i>Selaginella repanda</i> (Desv. ex Poir.) Spring	NT	450–790	g,r	12-016-001 ^u , 12-022-003 ^u , 12-082-062 ^u
<i>Selaginella wallichii</i> (Hook. & Grev.) Spring	HK	497–614	g	13-115-009 ^p , 13-116-007 ^s , 13-118-011 ^s , 13-118-012 ^s , 14-070-002 ^s
Ophioglossaceae				
<i>Botrychium formosanum</i> Tagawa (perhaps merely a form of B. daucifolium Wall. ex Hook. & Grev.) *	HY	1036–1197	g	13-098-231 ^p , 13-103-247 ^s
<i>Japanobotrychium lanuginosum</i> (Wall. ex Hook. & Grev.) Nishida ex Tagawa	NT	2200–2473	g,t1	12-007-001 ^s , 12-073-019 ^u
Marattiaceae				
<i>Angiopteris helferiana</i> C.Presl	HY	497–614	g	13-116-015 ^s , 13-118-007 ^u
Hymenophyllaceae				
<i>Crepidomanes campanulatum</i> (Roxb.) Panigrahi & Sarn. Singh	HY	1046–2400	t1,t2,t3,t4,t5	13-093-002 ^p , 13-094-143 ^s , 13-095-002 ^u , 13-101-293 ^p , 13-101-297 ^p , 13-103-251 ^p , 13-104-014 ^p , 13-104-009 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Crepidomanes</i> cf. <i>minutum</i> (Blume) K.Iwats.*	NT	2480–2480	r	12-066-023 ^s
<i>Crepidomanes</i> <i>latealatum</i> (Bosch.) Copel.	NT, HK&HY	715–3016	g,w,r,t1,t2,t3,t4,t5	12-007-003 ^u , 12-012-003 ^u , 12-048-006 ^s , 12-077-004 ^u , 12-077-006 ^s , 13-088-056 ^s , 13-098-219 ^p , 13-098-226 ^s , 13-099-025 ^p , 13-101-271 ^s , 13-101-292 ^s , 13-103-276 ^s , 13-103-279 ^p , 13-103-252 ^p , 13-103-277 ^p , 13-104-007 ^s , 13-104-014 ^s , 13-105-027 ^s , 13-105-028 ^s , 13-106-003 ^p , 14-031-013 ^u , 14-047-007 ^u , 14-047-227 ^p , 14-047-228 ^p , 14-048-004 ^p , 14-050-003 ^p , 14-050-004 ^s , 14-051-003 ^p , 14-051-004 ^u , 14-054-007 ^u , 14-054-008 ^u , 14-055-002 ^u , 14-057-005 ^p , 14-059-006 ^p , 14-060-011 ^u , 14-061-006 ^s , 14-066-240 ^s
<i>Didymoglossum</i> <i>sublimbatum</i> (Müll.Berol.) Ebihara & K.Iwats.	HK	614–909	w,t1	14-061-007 ^s , 14-066-246 ^u , 14-070-005 ^s
<i>Hymenophyllum</i> <i>badium</i> Hook. & Grev.	NT&HY	1168–2632	g,r,t1,t2,t3,t4	12-077-007 ^u , 13-076-079 ^s , 13-098-236 ^p , 13-102-262 ^s
<i>Hymenophyllum</i> <i>barbatum</i> (Bosch) Baker	HK&HY	1404–2600	w,t1,t2,t3,t4,t5	13-078-011 ^s , 13-085-119 ^p , 14-031-014 ^u , 14-042-009 ^u , 14-047-229 ^u , 14-048-005 ^u , 14-051-010 ^s
<i>Hymenophyllum</i> <i>corrugatum</i> Christ*	HK&HY	2676–3502	t1,t2,t3	14-015-002 ^u , 14-015-005 ^s
<i>Hymenophyllum</i> <i>exsertum</i> Wall. ex Hook.	NT, HK&HY	1168–2807	g,t1,t2,t3,t4	12-012-004 ^p , 12-035-001 ^u , 12-035-002 ^s , 12-074-011 ^s , 12-092-056 ^u , 12-097-025 ^s , 12-097-027 ^s , 13-074-065 ^s , 13-075-008 ^p , 13-102-260 ^s , 14-042-003 ^u
<i>Hymenophyllum</i> <i>polyanthos</i> (Sw.) Sw.	NT	1803–2959	t1,t2,t3,t4	12-003-009 ^s , 12-007-005 ^{su} , 12-035-003 ^u , 12-074-010 ^s , 12-097-024 ^u , 12-097-026 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Hymenophyllum simonsianum</i> Hook.*	HY	2371–3047	g,r,t1,t2,t3,t4	13-069-010 ^P , 13-072-057 ^P , 13-073-006 ^P , 13-077-093 ^S
<i>Hymenophyllum tenellum</i> D.Don	HK&HY	892–3138	g,w,r,t1,t2,t3,t4	13-064-043 ^P , 13-064-044 ^P , 13-064-047 ^P , 13-064-052 ^P , 13-064-053 ^P , 13-064-054 ^P , 13-064-055 ^P , 13-065-040 ^P , 13-066-036 ^S , 13-066-038b ^P , 13-066-039 ^P , 13-067-034 ^P , 13-067-035 ^P , 13-068-045 ^P , 13-068-047 ^P , 13-068-051 ^P , 13-069-011 ^P , 13-070-053 ^P , 13-075-012 ^P , 13-075-013 ^P , 13-076-080 ^P , 13-076-089 ^P , 13-077-101 ^S , 13-102-298 ^S , 14-060-009 ^P
<i>Vandenboschia auriculata</i> (Blume) Copel.	HY	1047–2078	r,t1,t2	13-088-045 ^S , 13-088-046 ^S , 13-088-047 ^S , 13-093-005 ^S , 13-094-160 ^P , 13-105-017 ^P
<i>Vandenboschia maxima</i> (Blume) Copel. *	HY	1051–1197	t1	13-098-216 ^P , 13-098-218 ^P , 13-101-290 ^S , 13-101-291 ^P
<i>Vandenboschia striata</i> (D.Don) Ebihara	HY	1047–1833	t1,t2	13-093-001 ^S , 13-098-222 ^P , 13-105-003 ^U
Gleicheniaceae				
<i>Dicranopteris taiwanensis</i> Ching & P.S.Chiu*	HY	497–497	g	13-118-009 ^S
Lygodiaceae				
<i>Lygodium flexuosum</i> (L.) Sw.	NT	450–1194	g,t1	12-016-011 ^U , 12-022-002 ^U , 12-082-067 ^S
Plagiogyriaceae				
<i>Plagiogyria glauca</i> (Blume) Mett.	HY	2804–3138	g,w,t1	13-070-052 ^S , 13-074-069 ^S
<i>Plagiogyria pycnophylla</i> (Kunze) Mett.	HY	2029–2839	g,w	13-074-066 ^S , 13-078-001 ^P , 13-079-082 ^P
Cibotiaceae				
<i>Cibotium barometz</i> (L.) J.Sm.	HY	505–519	g	13-115-010 ^S
Cyatheaceae				
<i>Alsophila andersonii</i> J.Scott ex Bedd.	HK&HY	497–1168	g	13-098-230 ^b , 13-103-269 ^b , 13-106-001 ^b , 13-118-013 ^P , 14-057-007 ^b , 14-069-004 ^b

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Alsophila costularis</i> Baker*	HY	527–1715	g	13-094-153 ^b
<i>Alsophila gigantea</i> Wall. ex Hook.	HK&HY	519–3047	g,t1	13-117-006 ^p , 14-069-003 ^b
<i>Alsophila khasyana</i> T.Moore ex Kuhn	HY	2078–2078	g	13-088-037 ^b
<i>Alsophila latebrosa</i> Wall. ex Hook.	HY	1168–1360	g	13-101-284 ^b , 14-050-011 ^b
<i>Alsophila spinulosa</i> (Wall. ex Hook.) R.M.Tryon	HK&HY	833–2039	g,t1	13-098-211 ^p , 13-098-239 ^p , 13-102-265 ^p , 14-031-011 ^b
<i>Sphaeropteris</i> <i>brunoniana</i> (Hook.) R.M.Tryon	HY	1168–2029	g,t1,t2	13-089-117 ^p , 13-099-014 ^b
Pteridaceae				
<i>Adiantum philippense</i> L.	NT	450–1209	g,t1	12-015-099 ^s , 12-016-005 ^u , 12-022-004 ^u , 12-022-005 ^s , 12-022-005 ^s , 12-057-003 ^u , 12-082-066 ^u
<i>Adiantum cf. incisum</i> C.Presl*	NT	566–788	g	12-082-065 ^u
<i>Antrophyum henryi</i> Hieron.*	HY	1047–1047	t1	13-105-013 ^s
<i>Antrophyum obovatum</i> Backer	HY	1714–1714	t1	13-095-007 ^s
<i>Antrophyum</i> <i>reticulatum</i> (G.Forst.) Kaulf.	HK&HY	909–1565	t1,t2,t3	13-098-229 ^s , 13-102-280 ^p , 13-103-267 ^s , 13-103-273 ^p , 13-105-002 ^s , 14-031-012 ^s , 14-054-022 ^s , 14-061-012 ^u
<i>Antrophyum</i> <i>wallichianum</i> M.G.Gilbert & X.C.Zhang	HK	892–1508	t1,t2,t3,t4	14-041-002 ^u , 14-048-009 ^u , 14-060-004 ^u
<i>Cerosora microphylla</i> (Hook.) R.M.Tryon	HY	2400–2607	g,r,t1	13-077-103 ^p , 13-078-005 ^p , 13-079-085 ^p , 13-080-113 ^s
<i>Coniogramme fraxinea</i> (Don) Diels	HY	1797–1988	g	13-090-012 ^p , 13-093-032 ^p
<i>Coniogramme petelotii</i> Tardieu	HK	1508–1508	g	14-041-013 ^u
<i>Coniogramme serrulata</i> (Blume) Fée	HY	2233–2600	g	13-078-004 ^s , 13-084-019 ^s , 13-087-108 ^p
<i>Haplopteris doniana</i> (Mett. ex Hieron.) E.H.Crane	HY	2233–2807	r,t1,t2,t3	13-075-004 ^s , 13-080-108 ^p
<i>Haplopteris elongata</i> (Sw.) E.H.Crane	HY	497–909	t1,t2,t3,t4	13-115-004 ^p , 13-118-006 ^s , 14-057-017 ^s , 14-059-005 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Haplopteris flexuosa</i> (Fée) E.H.Crane	NT, HK&HY	874–2632	w,t1,t2,t3,t4,t5	12-051-002 ^u , 12-051-003 ^u , 12-092-055 ^u , 12-096-025 ^u , 13-088-043 ^s , 13-091-002 ^s , 13-091-006 ^p , 13-092-096 ^s , 13-094-141 ^p , 13-095-014 ^s , 13-095-127 ^p , 13-095-128 ^p , 13-098-242 ^s , 13-101-295 ^p , 13-102-277 ^s , 13-104-015 ^s , 14-031-017 ^p , 14-032-007 ^s , 14-032-014 ^s , 14-032-016 ^s , 14-041-016 ^s , 14-047-021 ^s , 14-051-005 ^s , 14-051-006 ^s , 14-051-011 ^s , 14-055-010 ^s , 14-057-008 ^s , 14-057-014 ^s
<i>Haplopteris mediosora</i> (Hayata) X.C.Zhang	HY	2632–3136	t1,t2,t3	13-066-035 ^s , 13-067-042 ^p , 13-072-055 ^p , 13-073-009 ^s , 13-076-092 ^s
<i>Haplopteris sikkimensis</i> (Kuhn) E.H.Crane	HY	1168–1168	t1	13-102-288 ^s
<i>Haplopteris taeniophylla</i> (Copel.) E.H.Crane	NT&HY	2151–3003	r,t1,t2,t3,t4,t5	12-005-004 ^s , 12-007-014 ^s , 12-007-016 ^s , 13-076-091 ^s
<i>Pteris alata</i> Lam.	HY	497–527	g	13-116-005 ^p
<i>Pteris arisanensis</i> Tagawa*	HK&HY	892–1168	g	13-098-225 ^p , 13-102-263 ^p , 13-105-005 ^p
<i>Pteris aspericaulis</i> Wall. ex J. Agardh	NT, HK &HY	1036–3003	g,t1	12-005-003 ^s , 13-088-060 ^s , 13-090-011 ^s , 13-090-014 ^s , 13-093-018 ^s , 13-103-243 ^s , 13-104-017 ^s , 13-106-005 ^s , 14-041-014 ^s , 14-054-015 ^p
<i>Pteris biaurita</i> L.	NT&HY	519–1209	g	12-015-098 ^s , 12-057-004 ^s , 13-116-013 ^p , 14-054-003 ^s
<i>Pteris cretica</i> L.	NT&HK	1508–2471	g	12-069-001 ^s , 12-048-014 ^p , 14-031-023 ^s
<i>Pteris fauriei</i> Hieron.	HY	1051–2233	g	13-085-117 ^s , 13-106-022 ^s
<i>Pteris khasiana</i> (C.B.Clarke) Hieron.	HK&HY	1565–1833	g	13-092-001 ^{su} , 14-031-003 ^u
<i>Pteris longipes</i> D.Don	NT&HY	1168–1776	g	12-048-004 ^u , 12-077-002 ^s , 13-094-158 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Pteris pellucens</i> J.Agardh	HY	1168–1168	g	13-098-266 ^P
<i>Pteris puberula</i> Ching	HY	1715–2607	g	13-077-096 ^S
<i>Pteris spinescens</i> C.Presl	HY	1797–1833	g	13-092-007 ^P , 13-093-018 ^S
Dennstaedtiaceae				
<i>Dennstaedtia zeylanica</i> (Sw.) Zink ex Fraser-Jenk. & Kandel	HY	3138–3138	t1	13-064-060 ^S
<i>Histiopteris incisa</i> (Thunb.) J.Sm.	HY	1168–1168	g	13-102-286 ^P
<i>Microlepia</i> × <i>bipinnata</i> (Maxino) Shimura*	HK	1404–1448	g	14-047-009 ^U , 14-047-010 ^U
<i>Microlepia calvescens</i> (Wall. ex Hook.) C.Presl	HK	1404–1404	g	14-051-002 ^U
<i>Microlepia</i> <i>intramarginalis</i> (Tagawa) Seriz. *	HY	1168–1168	g	13-102-258 ^S
<i>Microlepia rhomboidea</i> (Wall. ex Kunze) Prantl	HY	527–1177	g	13-101-286 ^U , 13-106-028 ^S , 13-116-009 ^S , 14-061-009 ^U
<i>Microlepia strigosa</i> (Thunb.) C.Presl	HK&HY	1168–1665	g	13-098-234 ^S , 13-101-296 ^U , 13-102-284 ^S , 14-031-009 ^U , 14-041-006 ^U
<i>Monachosorum henryi</i> Christ	HY	2607–2839	g,r	13-072-064 ^P , 13-073-007 ^P , 13-074-074 ^P , 13-076-090 ^P
Cystopteridaceae				
<i>Acystopteris tenuisecta</i> (Blume) Tagawa	HY	2078–2078	g	13-088-055 ^P
Aspleniaceae				
<i>Asplenium aethiopicum</i> (Burm.f.) Bech.	NT	2011–2020	t1,t2,t3,t4	12-074-004 ^U
<i>Asplenium crinicaule</i> Hance	HY	874–1197	t1,t2	13-098-251 ^S , 14-057-012 ^S
<i>Asplenium ensiforme</i> Wall. ex Hook. & Grev.	NT&HY	892–3041	w,r,t1,t2,t3,t4	12-003-007 ^U , 12-005-005 ^P , 13-068-048 ^P , 13-070-049 ^P , 13-075-003 ^P , 13-077-100 ^P , 13-080-109 ^P , 13-102-261 ^P , 13-102-290 ^P , 14-060-008 ^P
<i>Asplenium falcatum</i> Lam.	HY	892–909	g,w,r	14-061-004 ^S
<i>Asplenium</i> <i>finlaysonianum</i> Wall. ex Hook	HY	1168–1168	g	13-102-276 ^P
<i>Asplenium</i> <i>griffithianum</i> Hook.	HY	678–1197	g,t1,t2	13-098-215 ^P , 13-101-273 ^P , 14-067-147 ^P

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Asplenium indicum</i> Sledge	HY	1036–2262	g,w,t1,t2,t3,t4	13-084-023 ^P
<i>Asplenium lacinioides</i> Fraser-Jenk., Pangtey & Khullar	HY	1714–2262	t1,t2	13-084-008 ^S , 13-085- 116 ^S , 13-088-049 ^P , 13- 088-059 ^P , 13-093- 017 ^P , 13-094-147 ^P
<i>Asplenium nidoides</i> Fraser-Jenk. & Kandel	HK&HY	505–1833	w,t1,t2,t3,t4,t5	13-098-209 ^P , 13-105- 009 ^P , 14-047-020 ^U , 14-066-242 ^U
<i>Asplenium nitidum</i> Sw.	HY	1059–1059	t1	13-104-005 ^P
<i>Asplenium normale</i> D.Don	HK&HY	715–1661	g,w,r,t1	13-098-223 ^P , 13-101- 302 ^P , 13-102-269 ^P , 13-105-001 ^P , 13-105- 030 ^P , 14-041-011 ^S , 14- 047-005 ^P , 14-054- 009 ^U , 14-059-009 ^S , 14- 066-243 ^S
<i>Asplenium</i> <i>paucivenosum</i> (Ching) Bir	HY	2607–2632	r	13-076-076 ^P , 13-077- 094 ^S
<i>Asplenium phyllitidis</i> D.Don	HK&HY	497–909	t1,t2,t3,t4	13-117-004a ^S , 13-118- 014 ^U , 14-061-014 ^U
<i>Asplenium</i> <i>prolongatum</i> Hook.	HK&HY	892–1197	t1,t2	13-098-207 ^P , 13-099- 001 ^P , 13-101-280 ^P , 13-105-004 ^P , 14-054- 023 ^U
<i>Asplenium sikkimbirii</i> Fraser-Jenk.*	HY	1168–1168	t1	13-098-232 ^S
<i>Asplenium</i> <i>simonsianum</i> Hook.*	HY	527–527	t1,t2,t3	13-116-017 ^P
<i>Asplenium tenuifolium</i> D.Don	NT	1753–2789	g,r,t1	12-007-002 ^U , 12-066- 022 ^U
<i>Asplenium varians</i> Wall. ex Hook. & Grev.*	HK	1565–1665	t1,t2	14-032-019 ^S
<i>Asplenium yoshinagae</i> Makino	NT, HK&HY	678–2789	g,w,t1,t2,t3,t4	12-007-009 ^S , 12-048- 005a ^S , 12-097-023 ^S , 13-085-126 ^S , 13-090- 013 ^S , 14-048-008 ^S , 14- 050-006 ^U , 14-066-254 ^S
<i>Hymenasplenium</i> <i>cheilosorum</i> (Kunze ex Mett.) Tagawa	HY	1168–1833	g,t1	13-093-009 ^P , 13-101- 285 ^P
<i>Hymenasplenium</i> <i>excisum</i> (C.Presl) S.Linds.	HY	1168–1168	r	13-098-221 ^P
Blechnaceae				
<i>Blechnopsis orientalis</i> (L.) C.Presl	HY	497–505	g	13-115-011 ^S

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
Athyriaceae				
<i>Athyrium</i> aff. <i>vermae</i> Fraser-Jenk. *	HY	1051–1059	g	13-104-016 ^s , 13-106-008 ^p
<i>Athyrium anisopterum</i> Christ*	NT	2151–2151	g	12-073-051 ^s
<i>Athyrium atkinsonii</i> Bedd.	NT	1745–3003	g	12-003-004 ^u
<i>Athyrium cumingianum</i> (C.Presl) Ching*	NT	450–585	g	12-022-001 ^u
<i>Athyrium davidii</i> (Franch.) Christ*	HY	3853–3853	g	13-055-016 ^s
<i>Athyrium decurrenti- alatum</i> (Hook.) Copel.*	HY	1168–2162	g	13-086-013 ^s , 13-098-238 ^p , 13-098-261 ^p , 13-102-268 ^s
<i>Athyrium dissitifolium</i> (Baker) C.Chr.	NT&HY	1492–3450	g,t1	12-012-018 ^u , 12-046-001 ^s , 12-046-006 ^u , 12-046-010 ^s , 13-065-045 ^s
<i>Athyrium drepanopterum</i> (Kunze) A.Braun ex Milde	NT&HY	1168–2151	g	12-015-094 ^s , 12-035-004 ^s , 13-102-294 ^s , 13-102-297 ^s
<i>Athyrium fimbriatum</i> (Wall.) T.Moore*	HY	3016–3502	g	13-067-040 ^s , 13-069-012 ^p , 14-015-006 ^u
<i>Athyrium foliolosum</i> T.Moore ex R.Sim*	HY	2029–2632	g,t1	13-076-087 ^p , 13-077-092 ^p , 13-077-104 ^p , 13-078-002 ^s , 13-078-006 ^p , 13-078-013 ^p , 13-079-088 ^s , 13-079-089 ^p , 13-088-053 ^u , 13-089-107 ^u
<i>Athyrium himalaicum</i> Ching ex Mehra & Bir*	HK	3603–3603	g,r	14-027-004 ^s
<i>Athyrium imbricatum</i> Christ*	HY	1036–1177	g	13-101-278 ^s , 14-054-002 ^s
<i>Athyrium mearnsianum</i> (Copel.) Alderw.*	HY	1168–1197	g	13-099-023 ^u , 13-102-295 ^u
<i>Athyrium nakanoi</i> Makino*	HY	2433–2433	g	13-083-081 ^p
<i>Athyrium opacum</i> (D.Don) Copel.	HY	1051–1197	g	13-099-002 ^p , 13-099-015 ^s , 13-101-301 ^s
<i>Athyrium puncticaule</i> (Blume) T.Moore*	HY	2162–2807	g	13-074-070 ^p , 13-074-072 ^p , 13-074-073 ^p , 13-075-009 ^p , 13-076-086 ^s , 13-086-005 ^p , 13-086-022 ^p , 13-086-026 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Athyrium</i> <i>quadripinnatifidum</i> (M.Kato) Seriz. (basionym of : <i>Cornopteris badia</i> Ching f. <i>quadripinnatifida</i> (M.Kato) W.M.Chu)*	HY	1168–2262	g	13-084-011 ^s , 13-098-208 ^p
<i>Athyrium roseum</i> Christ*	NT	2753–2753	g	12-041-005 ^u
<i>Athyrium rupicola</i> (Edgew. ex C.Hope) C.Chr.*	HY	3136–3863	g	13-054-016 ^s , 13-056-031 ^s , 13-067-044 ^s
<i>Athyrium setiferum</i> C.Chr.	HY	2433–3136	g,t1	13-065-043 ^p , 13-067-043 ^s , 13-077-099 ^p , 13-083-080 ^p
<i>Deparia boryana</i> (Willd.) M.Kato*	HY	1168–1833	g	13-093-011 ^p , 13-095-010 ^s , 13-102-274 ^p , 13-102-2964 ^p
<i>Diplazium bellum</i> Bir*	HY	1197–2433	g	13-088-054 ^s
<i>Diplazium</i> <i>chattagramicum</i> Ching*	HY	519–519	g	13-117-005 ^s
<i>Diplazium dilatatum</i> Blume	HK&HY	497–2162	g	13-086-027 ^p , 13-098-250 ^s , 13-099-010 ^p , 13-101-298 ^s , 13-115-005 ^p , 13-115-008 ^s , 14-047-008 ^s , 14-054-018 ^s , 14-061-008 ^u , 14-066-250 ^s , 14-067-143 ^u
<i>Diplazium doederleinii</i> (Luer ss.) Makino*	HY	1051–1168	g	13-098-264 ^p , 13-102-285 ^s , 13-106-019 ^p
<i>Diplazium donianum</i> (Mett.) Tardieu*	HK&HY	497–1448	g	13-115-006 ^s , 13-117-001 ^p , 14-047-016 ^u , 14-066-238 ^u
<i>Diplazium forrestii</i> (Ching ex Z.R.Wang) Fraser-Jenk. *	HK&HY	1051–2209	g	13-085-120 ^p , 13-090-003 ^s , 13-106-025 ^s , 14-032-015 ^u
<i>Diplazium kawakamii</i> Hayata*	HY	2078–2078	g	13-088-041 ^s
<i>Diplazium laxifrons</i> Rosenst.*	HY	1059–2557	g,w	13-079-084 ^s , 13-081-096 ^p , 13-104-004 ^s
<i>Diplazium spectabile</i> (Wall. ex Mett.) Ching	HY	1047–1988	g	13-102-275 ^s , 13-105-011 ^p
<i>Diplazium stoliczkae</i> Bedd.*	HY	2262–2632	g	13-076-081 ^s , 13-077-090 ^p , 13-084-002 ^p
<i>Diplazium succulentum</i> (C.B.Clarke) C.Chr.*	NT&HY	1776–2262	g	12-048-011 ^s , 13-084-001 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
Thelypteridaceae				
<i>Christella crinipes</i> (Hook.) Holttum	HY	1197–1197	g	13-099-022 ^s
<i>Christella dentata</i> (Forssk.) Brownsey & Jermy	NT	1753–2011	g	12-048-013 ^s , 12-074- 012 ^s
<i>Christella procera</i> (D.Don) Mazumdar	NT&HY	497–1665	g	12-046-009 ^s , 13-103- 242 ^u , 13-116-006 ^p , 13-116-008 ^s , 14-055- 005 ^u
<i>Christella siamensis</i> (Tagawa & K.Iwats.) Holttum*	HY	1046–1051	g	13-103-260 ^s
<i>Cyclogramma</i> <i>auriculata</i> (J.Sm.) Ching*	HY	2433–2433	g	13-083-084 ^u
<i>Glaphyopteridopsis</i> <i>erubescens</i> (Wall. ex Hook.) Ching	NT	2011–2011	g	12-074-002 ^u
<i>Metathelypteris</i> <i>decipiens</i> (C.B.Clarke) Ching	HY	1168–1988	g	13-090-006 ^s , 13-102- 271 ^s
<i>Metathelypteris flaccida</i> (Blume) Ching	HY	1168–1168	g	13-102-273 ^p
<i>Pronephrium</i> <i>articulatum</i> (Houlston & T.Moore) Holttum*	HY	527–527	g	13-116-014 ^p
<i>Pronephrium</i> <i>lakhimpurens</i> (Rosenst.) Holttum	HY	1797–1833	g	13-092-005 ^s
<i>Pronephrium</i> <i>triphyllum</i> (Sw.) Holttum	HY	505–527	g	13-115-016 ^p , 13-116- 010 ^s
<i>Sphaerostephanos</i> <i>validus</i> (Christ) Holttum*	NT	790–1197	g	12-016-012 ^s , 12-057- 002 ^u
<i>Thelypteris loyalii</i> Fraser-Jenk.*	HY	1047–1168	g	13-102-266 ^s , 13-105- 012 ^p
<i>Thelypteris ornatipes</i> Fraser-Jenk.*	HY	1177–1197	g	13-099-003 ^s
Hypodematiaceae				
<i>Leucostegia truncata</i> (D.Don) Fraser-Jenk.*	NT&HY	1429–2789	g,w,t1,t2,t3,t4,t5	12-007-020 ^s , 12-012- 011 ^u , 13-093-025 ^p , 13-093-030 ^p
Dryopteridaceae				
<i>Arachniodes assamica</i> (Kuhn) Ohwi	HY	1833–1833	g	13-093-008 ^s
<i>Arachniodes henryi</i> (Christ) Ching	HY	1833–1833	g	13-093-004 ^p , 13-093- 016 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Arachniodes spectabilis</i> (Ching) Ching*	NT, HK&HY	527–2433	g	12-048-008 ^s , 13-081-098 ^u , 13-083-082 ^u , 13-086-004 ^u , 13-090-002 ^u , 13-093-015 ^u , 13-101-287 ^u , 14-032-036 ^u , 14-041-004 ^u , 14-048-003 ^u , 14-050-008 ^u
<i>Arachniodes superba</i> Fraser-Jenk.*	HY	2557–2804	g,r	13-074-064 ^s
<i>Bolbitis appendiculata</i> (Willd.) K.Iwats.	HY	678–715	g,t1	14-066-245 ^u , 14-067-145 ^s
<i>Bolbitis crispatula</i> (Wall.) Ching*	NT	1209–1209	g	12-015-101 ^s
<i>Bolbitis heteroclita</i> (C.Presl) Ching	HY	497–1197	g,w,r,t1,t2	13-098-248 ^p , 13-099-019 ^s , 13-103-259 ^p , 13-118-008 ^p , 14-054-019 ^u , 14-066-239 ^u
<i>Bolbitis sinensis</i> K.Iwats.	NT&HY	715–1776	g	12-048-002 ^s , 14-066-244 ^s
<i>Ctenitis apiciflora</i> (Wall. ex Mett.) Ching*	HY	2262–2839	g,w	13-072-060 ^p , 13-074-067 ^p , 13-075-067 ^p , 13-079-081 ^p
<i>Ctenitis clarkei</i> (Baker) Ching	HY	1715–3138	g,w,t1,t2	13-064-050 ^p , 13-072-056 ^p
<i>Ctenitis dumrongii</i> Tagawa & K.Iwats.*	HY	2233–2262	g	13-084-021 ^u
<i>Dryopteris acutodentata</i> Ching*	HK	3575–3603	g,r	14-027-012 ^s
<i>Dryopteris alpestris</i> Tagawa*	HY	3834–4057	g	13-049-010 ^p , 13-056-030 ^p
<i>Dryopteris caroli-hopei</i> Fraser-Jenk*	NT	1492–2473	g	12-007-015 ^s , 12-012-006 ^p , 12-012-015 ^s
<i>Dryopteris cochleata</i> (Buch.-Ham. ex D.Don) C.Chr.	NT	450–2011	g,r,t1	12-015-095 ^u , 12-015-096 ^p , 12-015-100 ^p , 12-016-008 ^s , 12-016-015 ^p , 12-017-101 ^p , 12-017-102 ^p , 12-017-103 ^p , 12-017-104 ^u , 12-017-105 ^u , 12-017-106 ^p , 12-017-107 ^u , 12-017-108 ^p , 12-017-109 ^s , 12-017-110 ^p , 12-074-001 ^u , 12-087-004 ^s
<i>Dryopteris diffracta</i> (Baker) C. Chr.	HY	1177–1197	g	13-099-026 ^s , 13-101-300 ^u
<i>Dryopteris hirtipes</i> (Blume) Kuntze subsp. <i>atrata</i> (Wall. ex Kunze) Fraser- Jenk.	NT, HK&HY	1508–1988	g,t1	12-048-007 ^u , 13-090-008 ^s , 14-031-004 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Dryopteris neoassamensis</i> Ching*	HK	1404–2078	g	14-051-008 ^s
<i>Dryopteris paleolata</i> (Pic.Serm.) Li Bing Zhang*	HY	2162–3138	g,w	13-064-049 ^s , 13-068-050 ^p , 13-072-062 ^s , 13-073-004 ^p , 13-078-009 ^p , 13-081-100 ^p , 13-084-013 ^p , 13-086-002 ^p , 13-087-101 ^p
<i>Dryopteris peranema</i> Li Bing Zhang*	NT	2957–2957	g	12-003-003 ^s
<i>Dryopteris pseudocaenopteris</i> (Kunze) Li Bing Zhang*	NT, HK&HY	1168–2632	g,t1	12-007-023 ^u , 12-073-053 ^s , 13-076-085 ^p , 13-076-088 ^p , 13-077-089 ^p , 13-077-105 ^s , 13-080-114 ^p , 13-085-113 ^p , 13-085-114 ^p , 13-085-115 ^p , 13-085-125 ^p , 13-086-010 ^p , 13-088-033 ^p , 13-092-003 ^p , 13-102-293 ^s , 14-031-015 ^u , 14-032-004 ^u , 14-041-012 ^p , 14-042-006 ^u , 14-048-006 ^s , 14-051-007 ^s
<i>Dryopteris rubrobrunnea</i> W.M.Chu*	HY	2233–2607	g	13-077-098 ^s , 13-083-085 ^p , 13-084-017 ^p , 13-084-018 ^p
<i>Dryopteris scottii</i> (Bedd.) Ching	NT, HK&HY	892–1833	g,w	13-093-010 ^s , 13-098-213 ^p , 13-099-004 ^p , 13-101-282 ^p , 13-102-278 ^p , 14-060-003 ^u , 14-061-002 ^u
<i>Dryopteris sikkimensis</i> (Bedd.) Kuntze*	HY	2807–3138	g,t1	13-064-051 ^s , 13-065-044 ^p , 13-066-037 ^p , 13-067-037 ^p , 13-072-061 ^p , 13-075-061 ^p
<i>Dryopteris sparsa</i> (D.Don) Kuntze	HK&HY	497–1665	g,w,t1	13-102-292 ^p , 13-103-261 ^u , 13-105-007 ^p , 13-106-021 ^u , 13-118-005 ^p , 14-031-018 ^u , 14-032-009 ^u , 14-054-004 ^u , 14-054-016 ^p , 14-055-006 ^u , 14-057-002 ^u
<i>Dryopteris stenolepis</i> (Baker) C.Chr.	HY	1833–1833	g	13-093-022 ^p
<i>Dryopteris vidyae</i> Fraser-Jenk.*	HY	1046–1046	g	13-103-263 ^u
<i>Dryopteris wallichiana</i> (Spreng.) Hyl.	NT&HY	2557–3003	g	12-003-002 ^u , 13-079-086 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Dryopteris woodsii</i> sora Hayata*	HK	3400–3603	g,t1	14-015-004 ^u , 14-027-003 ^s
<i>Dryopteris pseudosparsa</i> Ching*	HY	833–909	g,w	14-057-003 ^u , 14-059-004 ^u
<i>Elaphoglossum marginatum</i> (Wall. ex Fée) T.Moore*	NT, HK&HY	1360–2471	w,t1,t2,t3,t4,t5	12-097-028 ^s , 13-085-123 ^p , 13-086-009 ^p , 13-088-035 ^s , 13-090-005 ^p , 14-050-013 ^s
<i>Elaphoglossum stelligerum</i> (Wall. ex Baker) T.Moore ex Salomon*	NT, HK&HY	1168–1803	w,t1,t2,t3,t4	12-046-007 ^u , 12-051-005 ^u , 12-078-001 ^u , 13-098-243 ^p , 13-098-262 ^s , 14-031-026 ^u , 14-032-011 ^u , 14-032-012 ^s , 14-048-007 ^u
<i>Elaphoglossum yoshinagae</i> (Yatabe) Makino*	HY	874–874	t1	14-057-010 ^s
<i>Lomagramma sorbifolia</i> (Willd.) Ching	HY	519–527	t1	13-116-020 ^s , 13-117-010 ^p
<i>Pleocnemia cf. submembrancea</i> (Hayata) Tagawa & K.Iwats.*	HY	614–678	g	14-067-178 ^s
<i>Polystichum atkinsonii</i> Bedd.*	HY	3136–3136	r	13-067-039 ^s
<i>Polystichum discretum</i> (D.Don) J.Sm.*	NT&HY	1168–2480	g	12-066-021 ^u , 13-102-272 ^s , 13-102-287 ^s
<i>Polystichum hookerianum</i> (C.Presl) C.Chr.	HY	2039–2233	g	13-086-003 ^p , 13-088-036 ^p
<i>Polystichum lentum</i> (D.Don) T.Moore*	NT&HY	1833–2480	g,r	12-073-052 ^s , 13-090-015 ^p , 13-093-023 ^s
<i>Polystichum longipaleatum</i> Christ*	HY	2371–2829	g	13-072-065 ^s , 13-075-007 ^p , 13-077-088 ^p , 13-083-078 ^p
<i>Polystichum manmeiense</i> (Christ) Nakaike*	NT&HY	2433–2789	g,r	12-041-006 ^s , 13-076-077 ^s , 13-083-076 ^s
<i>Polystichum moupinense</i> (Franch.) Bedd.*	HK	3603–3603	g	14-027-002 ^u
<i>Polystichum scariosum</i> (Roxb.) C.V.Morton*	HY	892–1833	g	13-093-020 ^u , 13-095-004 ^s , 14-060-005 ^u , 14-061-010 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Polystichum semifertile</i> (C.B.Clarke) Ching*	NT, HK&HY	1447–3003	g,w,r,t2	12-007-011 ^u , 12-037-001 ^u , 12-037-003 ^u , 12-041-001 ^u , 12-048-003 ^u , 12-066-020 ^u , 12-069-003 ^u , 12-073-054 ^u , 12-076-049 ^u , 12-076-050 ^u , 12-077-001 ^u , 12-077-003 ^u , 13-081-097 ^p , 13-083-075 ^s , 13-083-083 ^p , 13-087-100 ^p , 13-090-010 ^s , 14-031-002 ^u , 14-042-002 ^u , 14-048-002 ^u
<i>Polystichum squarrosus</i> (D.Don) Fée*	NT	2471–2789	g	12-037-002 ^u
<i>Polystichum woodsioides</i> Christ*	HK&HY	3588–3863	g,r	13-054-017 ^p , 13-057-001 ^s , 13-057-002 ^p , 13-057-003 ^s , 13-057-004 ^p , 14-026-002 ^s
<i>Polystichum pseudotsus-simense</i> Ching	NT	2665–2959	g	12-003-001 ^{su} , 12-041-002 ^u , 12-041-003 ^u , 12-041-007 ^u
Nephrolepidaceae				
<i>Nephrolepis cordifolia</i> (L.) C.Presl	HY	497–1197	w,t1,t2,t4,t5	13-098-224 ^p , 13-098-249 ^p , 13-099-009 ^p , 13-099-017 ^p , 13-101-281 ^p , 13-101-288 ^p , 13-102-291 ^p , 13-104-008 ^p , 13-106-020 ^p , 13-118-010 ^p , 14-061-005 ^s
Tectariaceae				
<i>Tectaria coadunata</i> (J.Sm.) C.Chr.	NT	790–1449	g,t1	12-016-009 ^u , 12-016-010 ^u
<i>Tectaria dubia</i> (C.B.Clarke & Baker) Ching*	HY	678–715	g	14-067-142 ^s
<i>Tectaria fuscipes</i> (Wall. ex Bedd.) C.Chr.	HY	519–519	g	13-117-009 ^s
<i>Tectaria ingens</i> (Atk. ex C.B.Clarke) Holttum*	HY	1168–1833	g	13-093-007 ^s , 13-102-267 ^p
<i>Tectaria polymorpha</i> (Wall. ex Hook.) Copel.	HK	1360–1665	g	14-032-002 ^s
Oleandraceae				
<i>Oleandra musifolia</i> (Blume) C.Presl	NT	1492–1492	t2,t3	12-046-008 ^s
<i>Oleandra neriiformis</i> Cav.	HK&HY	1197–1797	t1,t2,t3,t4,t5	13-099-005 ^s , 14-031-024 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Oleandra wallichii</i> (Hook.) C.Presl	NT, HK&HY	1508–3047	t1,t2,t3,t4,t5	12-007-007 ^s , 13-069-006 ^p , 13-073-002 ^p , 13-076-078 ^p , 13-084-015 ^p , 14-041-017 ^s
Davalliaceae				
<i>Davallia assamica</i> (Bedd.) Baker	HK&HY	1036–2807	g,w,t1,t2,t3,t4,t5	13-092-095 ^p , 13-093-027 ^p , 13-094-154 ^p , 13-094-149 ^p , 13-095-001 ^s , 13-095-009 ^s , 13-098-220 ^p , 13-098-237 ^p , 13-099-018 ^p , 13-099-024 ^p , 13-101-272 ^p , 13-101-276 ^p , 13-102-270 ^p , 13-103-244 ^b , 13-105-010 ^p , 13-105-018 ^p , 13-106-006 ^s , 13-106-013 ^p , 13-106-014 ^p , 14-031-025 ^u , 14-032-005 ^u , 14-041-015 ^u , 14-047-004 ^u , 14-054-012 ^u , 14-055-008 ^u
<i>Davallia denticulata</i> (Burm.f.) Mett. ex Kuhn	HY	527–527	t1	13-116-001 ^s
<i>Davallia griffithiana</i> Hook.	HY	519–1197	g,t3,t4,t5	13-106-017 ^p , 13-117-007 ^s
<i>Davallia multidentata</i> Hook.*	HY	1714–2078	w,t1,t2,t3,t4,t5	13-088-052 ^p , 13-089-111 ^p , 13-090-009 ^s , 13-095-011 ^p
<i>Davallia perdurans</i> Christ	HY	2600–2600	t2	13-078-007 ^s
<i>Davallia pulchra</i> D.Don	NT, HK&HY	847–3003	w,t1,t2,t3,t4,t5	12-003-005 ^s , 12-005-001 ^s , 12-094-001 ^u , 14-041-003 ^u , 14-042-007 ^u , 14-047-002 ^u , 14-050-007 ^s
<i>Davallia trichomanoides</i> Blume	NT&HY	505–1492	t1,t2,t3,t4,t5	12-092-057 ^u , 12-092-058 ^u , 13-103-262 ^s , 13-115-020 ^p , 14-057-018 ^u , 14-059-007 ^u , 14-066-241 ^u , 14-067-144 ^u
Polypodiaceae				
<i>Aglaomorpha coronans</i> (Wall. ex Mett.) Copel.	HY	497–1168	g,w,t1,t2,t3,t4,t5	13-098-246 ^p , 13-102-279 ^p , 13-103-257 ^p , 13-106-015 ^p , 13-115-021 ^p , 13-115-023 ^u , 14-055-003 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Aglaomorpha delavayi</i> (Christ) Hovenkamp & S.Linds.*	NT	2082–2184	t1,t2,t3,t4,t5	12-012-014 ^s
<i>Aglaomorpha parishii</i> (Bedd.) Hovenkamp & S.Linds.*	HY	1046–1046	t1	13-103-275 ^s
<i>Aglaomorpha</i> <i>propinqua</i> (Wall. ex Mett.) Hovenkamp & S.Linds.	NT, HK&HY	892–1665	g,w,t1,t2,t3,t4,t5	12-046-004 ^p , 13-098- 214 ^p , 13-101-274 ^p , 13-101-294 ^p , 13-102- 259 ^p , 13-106-007 ^p , 13-106-026 ^p , 14-031- 008 ^p , 14-032-008 ^s , 14- 041-007 ^s , 14-054- 006 ^u , 14-061-013 ^s
<i>Aglaomorpha</i> <i>quercifolia</i> (L.) Hovenkamp & S.Linds.	HY	505–505	t4	13-115-002 ^p
<i>Arthromeris</i> <i>amplexifolia</i> Ching*	NT	1595–1745	t1,t2,t3,t4	12-051-004 ^s
<i>Arthromeris</i> <i>cyrtomioides</i> S.G.Lu & C.D.Xu*	HY	1988–2233	t2,t3,t4,t5	13-086-016 ^p , 13-087- 104 ^p , 13-088-058 ^u
<i>Arthromeris elegans</i> Ching*	HY	1051–2078	t2,t3,t4,t5	13-088-050 ^u , 13-106- 016 ^u
<i>Arthromeris himalovata</i> Fraser-Jenk. & Kandel*	HY	2804–3133	t1,t2,t3,t4	13-066-040 ^s , 13-070- 047 ^p , 13-072-059 ^p
<i>Arthromeris lehmannii</i> (Mett.) Ching	NT&HY	1168–3136	g,t1,t2,t3,t4,t5	12-007-017 ^{su} , 12-012- 005 ^u , 12-057-001 ^u , 12-069-002 ^s , 13-065- 042 ^p , 13-068-049 ^p , 13-069-001 ^p , 13-070- 051 ^p , 13-081-099 ^s , 13- 084-010 ^p , 13-084- 012 ^s , 13-098-245a ^p
<i>Arthromeris tomentosa</i> W.M.Chu*	HY	2162–2400	t1,t2,t3,t4,t5	13-080-102 ^s , 13-086- 028 ^p , 13-087-105 ^p
<i>Arthromeris</i> <i>wallichiana</i> (Spreng.) Ching	HY	1797–2434	t2,t3,t4,t5	13-080-115 ^p , 13-082- 080 ^p , 13-085-121 ^p
<i>Arthromeris wardii</i> (C.B.Clarke)	HY	2371–3047	t1	13-069-008 ^s , 13-081- 102 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Goniophlebium amoenum</i> (Wall. ex Mett.) Bedd.	HK&HY	678–3047	g,w,r,t1,t2,t3,t4,t5	13-069-004 ^P , 13-069- 005 ^P , 13-069-009 ^P , 13-070-048 ^P , 13-071- 002 ^P , 13-080-110 ^P , 13-081-101 ^P , 13-081- 103 ^P , 13-084-007 ^P , 13-084-020 ^S , 13-086- 011 ^P , 13-086-015 ^U , 13-086-023 ^P , 13-087- 102 ^P , 13-088-040 ^P , 13-088-051 ^P , 13-091- 005 ^P , 13-093-029 ^P , 13-093-035 ^S , 13-093- 031 ^P , 13-094-155 ^P , 13-095-137 ^P , 13-098- 258 ^U , 13-099-007 ^P , 13-101-275 ^P , 13-101- 299 ^S , 13-103-265 ^P , 13- 103-282 ^P , 13-104- 001 ^S , 14-031-006 ^U , 14- 032-034 ^U , 14-047- 018 ^S , 14-054-017 ^U , 14- 057-004 ^U , 14-060-007 ^P
<i>Goniophlebium argutum</i> (Wall. ex Hook.) J.Sm. ex Hook.	NT&HY	1492–2839	g,t1,t2,t3,t4,t5	12-007-018 ^{PS} , 12-048- 010 ^U , 12-065-045 ^S , 13- 072-063 ^S , 13-078- 008 ^P , 13-084-009 ^P , 13-085-118 ^S
<i>Goniophlebium bourretii</i> (C.Chr. & Tardieu) X.C.Zhang*	HY	1046–1046	t2,t3	13-103-255 ^S
<i>Goniophlebium lachnopus</i> (Wall. ex Hook.) J.Sm.*	NT	2082–2765	t1,t2,t3,t4,t5	12-007-019 ^S
<i>Goniophlebium manmeiense</i> (Christ) Rödl-Linder	NT, HK&HY	1404–2480	w,t1,t2,t3,t4,t5	12-007-021 ^U , 12-012- 012 ^S , 12-012-013 ^S , 13- 085-122 ^S , 13-087- 099 ^S , 14-047-011 ^U
<i>Goniophlebium mengtzeense</i> (Christ) Rödl-Linder*	NT&HY	2029–3003	t1,t3,t4,t5	12-005-002 ^S , 13-089- 110 ^S
<i>Goniophlebium niponicum</i> (Mett.) Bedd.*	HK&HY	892–1565	w,t1,t2,t3,t4,t5	13-098-227 ^P , 13-102- 283 ^S , 13-104-011 ^S , 13- 105-014 ^S , 13-106- 027 ^P , 14-031-016 ^U , 14-055-004 ^U
<i>Goniophlebium subauriculatum</i> (Blume) C.Presl	HY	505–527	t1,t3	13-115-015 ^U , 13-116- 004 ^S

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Gymnogrammitis dareiformis</i> (Hook.) Ching ex Tardieu & C.Chr.	NT	2082–2473	g,t1,t2,t3,t4	12-007-006 ^u
<i>Lemmaphyllum carnosum</i> (Wall. ex J.Sm.) C.Presl	HK&HY	497–2078	w,t1,t2,t3,t4,t5	13-088-039 ^p , 13-088- 064 ^s , 13-094-162 ^p , 13- 094-163 ^p , 13-095- 008 ^p , 13-095-126 ^p , 13-098-210 ^p , 13-098- 235 ^p , 13-098-263 ^p , 13-098-267 ^p , 13-099- 008 ^s , 13-099-011 ^s , 13- 099-012 ^s , 13-099- 013 ^s , 13-101-279 ^p , 13- 103-241 ^p , 13-103- 256 ^p , 13-103-266 ^p , 13-103-271 ^p , 13-104- 010 ^p , 13-104-012 ^p , 13-105-008 ^p , 13-105- 023 ^p , 13-105-027 ^p , 13-105-025 ^p , 13-106- 018 ^p , 13-115-013 ^s , 13- 117-002 ^p , 13-117- 003 ^p , 13-118-001 ^p , 14-031-014a ^u , 14-050- 010 ^s , 14-054-011 ^s , 14- 054-024 ^p , 14-055-007 ^u
<i>Lemmaphyllum microphyllum</i> C.Presl*	HY	833–909	t1,t3	14-057-006 ^u , 14-059- 008 ^u , 14-060-006 ^s
<i>Lemmaphyllum rostratum</i> (Bedd.) Tagawa	HY	1715–2162	t1,t2,t3,t4	13-086-008 ^p , 13-088- 038 ^p , 13-089-108 ^p , 13-092-009 ^p , 13-093- 021 ^p , 13-094-150 ^p
<i>Lepidomicrosorium superficiale</i> (Blume) Li Wang	HK&HY	1360–2162	g,r,t1,t2	13-086-006 ^p , 13-092- 004 ^p , 13-093-003 ^u , 13-093-033 ^p , 13-094- 142 ^p , 14-031-005 ^p , 14-031-007 ^u
<i>Lepisorus bicolor</i> (Takeda) Ching*	NT&HY	2082–3047	t1,t2,t3,t4,t5	12-003-008 ^u , 13-068- 046 ^p , 13-069-013 ^p , 13-069-014 ^p
<i>Lepisorus contortus</i> (Christ) Ching	HY	497–2233	t1,t2,t3,t4,t5	13-086-018 ^s , 13-087- 109 ^p , 13-088-065 ^p , 13-094-161 ^p , 13-098- 244 ^s , 13-103-280 ^p , 13- 105-026 ^p , 13-106- 023 ^s , 13-118-003 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Lepisorus henryi</i> (Hieron. ex C.Chr.) Li Wang	HK&HY	1046–1714	w,t1,t2,t3,t4	13-095-015 ^s , 13-102- 282 ^s , 13-103-270 ^s , 13- 104-006 ^s , 13-105- 020 ^s , 13-106-030 ^s , 14- 050-002 ^s
<i>Lepisorus loriformis</i> (Wall. ex Mett.) Ching*	HY	2029–2839	t1,t2,t3,t4,t5	13-073-001 ^p , 13-073- 008 ^p , 13-074-068 ^p , 13-077-095 ^p , 13-087- 103 ^p , 13-087-110 ^p , 13-089-115 ^p , 13-089- 116 ^s
<i>Lepisorus macrosphearus</i> (Baker) Ching	HY	1177–2433	t1,t2,t3,t4,t5	13-086-019 ^p , 13-087- 111 ^p , 13-095-135 ^s
<i>Lepisorus mehrae</i> Fraser-Jenk.*	NT&HY	2167–2807	w,t1,t2,t3,t4	12-012-009 ^u , 13-075- 001 ^s
<i>Lepisorus mucronatus</i> (Fée) Li Wang*	HY	497–1715	w,t1,t2,t3,t4	13-094-148 ^s , 13-098- 247 ^s , 13-098-252 ^s , 13- 098-253 ^s , 13-101- 277 ^s , 13-103-272 ^s , 13- 105-006 ^s , 13-105- 021 ^s , 13-105-029 ^s , 13- 106-009 ^s , 13-106- 010 ^s , 13-106-011 ^s , 13- 106-031 ^s , 13-106- 032 ^s , 13-118-002 ^s , 14- 059-002 ^s
<i>Lepisorus nudus</i> (Hook.) Ching*	NT, HK&HY	1046–2233	g,w,t1,t2,t3,t4,t5	12-046-003a ^s , 12-071- 001 ^u , 12-074-007 ^u , 13-095-012 ^s , 13-098- 254 ^u , 13-103-278 ^s , 14- 032-013 ^u , 14-041-009 ^p
<i>Lepisorus scolopendrium</i> (Ching) Mehra & Bir	NT	1194–2789	g,t1,t2,t3,t4,t5	12-012-010 ^u , 12-046- 002 ^u , 12-046-003 ^u , 12-071-002 ^u
<i>Lepisorus spicatus</i> (L.f.) Li Wang*	HY	874–1197	w,t1,t4	14-054-013 ^u , 14-057- 009 ^p
<i>Lepisorus subconfluens</i> Ching	HK&HY	715–1833	w,t1,t2,t3,t4	13-093-026 ^p , 13-098- 255 ^s , 13-104-002 ^p , 14- 032-018 ^u , 14-048- 012 ^u , 14-066-253 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Lepisorus sublinearis</i> (Baker ex Takeda) Ching	NT, HK&HY	1168–2839	t1,t2,t3,t4,t5	12-076-051 ^s , 13-072-058 ^p , 13-073-005 ^p , 13-075-005 ^p , 13-076-091 ^{bs} , 13-077-097 ^p , 13-079-087 ^p , 13-081-104 ^p , 13-084-014 ^s , 13-086-021 ^u , 13-089-109 ^p , 13-090-016 ^p , 13-091-003 ^p , 13-093-019 ^p , 13-094-145 ^p , 13-095-130 ^s , 13-098-255(b) ^s , 13-102-281 ^p , 14-042-008 ^u
<i>Leptochilus chittagongensis</i> Fraser-Jenk. & Gias*	HY	1051–1051	w,t1,t2	13-106-004 ^u
<i>Leptochilus ellipticus</i> (Thunb.) Noot.	HY	1448–1833	g	13-093-024 ^p , 14-047-017 ^s
<i>Leptochilus hemionitideus</i> (C.Presl) Noot.	NT&HY	833–1776	g,w,r,t1,t2	12-048-001 ^u , 13-098-212 ^p , 13-098-259 ^u , 13-103-240 ^s , 13-105-022 ^s , 13-106-002 ^u , 14-054-026 ^u
<i>Leptochilus insignis</i> (Blume) Fraser-Jenk.	HY	1714–2078	g,r,t1	13-088-042 ^p , 13-093-006 ^p
<i>Leptochilus macrophyllus</i> (Blume) Noot.*	HY	614–614	t1	14-070-004 ^s
<i>Leptochilus minor</i> Fée*	HY	497–1047	t1	13-105-031 ^p , 13-118-004 ^s
<i>Leptochilus pedunculatus</i> (Hook. & Grev.) Fraser-Jenk.	HY	497–2162	g,w,r,t1,t2	13-086-007 ^p , 13-086-024 ^p , 13-088-032 ^p , 13-089-105 ^p , 13-090-004 ^p , 13-092-006 ^p , 13-094-144 ^p , 13-103-249 ^p , 13-103-258 ^p , 13-105-015 ^p , 13-115-007 ^u , 13-116-018 ^s , 14-047-003 ^s , 14-059-003 ^u
<i>Loxogramme chinensis</i> Ching	NT	1753–2753	r,t1,t2,t3,t4	12-007-012 ^s
<i>Loxogramme porcata</i> M.G. Price*	HK&HY	678–1797	t1,t2,t3,t4	13-094-156 ^p , 13-095-006 ^p , 13-095-013 ^p , 13-098-241 ^p , 13-099-021 ^p , 13-103-248 ^s , 13-103-274 ^p , 13-103-283 ^p , 14-032-006 ^s , 14-066-252 ^s

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Loxogramme subecostata</i> (Hook.) C.Chr.*	NT	2181–2181	t1,t2	12-012-007 ^s
<i>Micropolypodium sikkimense</i> (Hieron.) X.C.Zhang*	HY	2400–3138	t1,t2,t3	13-064-045 ^p
<i>Microsorium aichmophyllum</i> (Alston) Fraser-Jenk.	HY	2078–2262	g,t1,t2	13-084-003 ^s
<i>Microsorium cuspidatum</i> (D. Don) Tagawa	HK&HY	909–1447	t1,t2,t3,t4,t5	13-098-257 ^p , 13-099-016 ^p , 14-048-010 ^u , 14-050-009 ^s
<i>Microsorium membranaceum</i> (D.Don) Ching	NT&HY	1073–1776	g,w,t1,t2,t3,t4,t5	12-015-093 ^s , 12-048-005 ^s , 13-095-003 ^u
<i>Microsorium punctatum</i> (L.) Copel.	HK&HY	505–1059	t1,t2,t3,t4	13-104-013 ^p , 13-115-003 ^p , 13-116-002 ^p , 13-117-004 ^p , 14-066-249 ^u
<i>Neolepisorus zippelii</i> (Blume) Li Wang	HK&HY	833–1197	g,t1,t3,t4	13-098-260 ^p , 13-099-006 ^p , 13-103-253 ^u , 13-103-246 ^p , 14-054-005 ^u , 14-061-003 ^u
<i>Platyserium wallichii</i> Hook.	NT	566–1073	t1,t2,t3,t4	12-028-001 ^p
<i>Prosaptia khasyana</i> (Hook.) C.Chr. & Tardieu	HY	909–909	t3	14-061-011 ^u
<i>Pyrrosia costata</i> (Wall. ex C.Presl) Tagawa & K.Iwats.*	HY	678–1197	t1,t2,t3,t4,t5	13-098-228 ^p , 13-101-283 ^p , 13-102-289 ^p , 13-103-250 ^p , 13-103-254 ^p , 13-105-016 ^p , 13-105-032 ^p , 13-106-029 ^p , 14-054-010 ^p , 14-054-025 ^u , 14-060-012 ^p , 14-060-013 ^s , 14-066-247 ^u
<i>Pyrrosia heteractis</i> (Mett. ex Kuhn) Ching	HK&HY	1508–2078	t1,t2,t3,t4,t5	13-088-061 ^s , 13-094-151 ^p , 14-031-022 ^s , 14-041-005 ^u
<i>Pyrrosia laevis</i> (J.Sm. ex Bedd.) Ching*	HY	833–874	t1,t2	14-057-013 ^s
<i>Pyrrosia lanceolata</i> (L.) Farw.	HY	505–715	t1,t2,t3,t4	13-115-014 ^p , 13-115-018 ^p , 13-116-011 ^p , 13-116-016 ^p , 13-117-008 ^s , 14-066-248 ^s , 14-070-003 ^s
<i>Pyrrosia lingua</i> (Thunb.) Farw.	HY	833–909	t2,t3,t4	14-057-016 ^u , 14-060-010 ^p

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Pyrrosia mannii</i> (Giesenh.) Ching*	HY	715–715	t1	14-066-251 ^u
<i>Pyrrosia</i> <i>nummulariifolia</i> (Sw.) Ching	HY	505–505	t3	13-115-019 ^s
<i>Pyrrosia tonkinensis</i> (Giesenh.) Ching*	HK	1565–1565	t3,t4	14-031-019 ^s
<i>Pyrrosia flocculosa</i> (D.Don) Ching	HY	1833–1833	t1	13-093-028 ^s
<i>Pyrrosia subfurfuracea</i> (Hook.) Ching	HK&HY	1508–1715	t1,t3,t4,t5	13-094-164 ^p , 13-095- 134 ^u , 14-041-018 ^u
<i>Selliguea ebenipes</i> (Hook.) S.Linds.	NT&HY	1197–3138	t1,t2,t3,t4,t5	12-003-006 ^u , 13-064- 057 ^p , 13-066-041 ^p , 13-067-041 ^p , 13-069- 002 ^p , 13-069-003 ^p , 13-071-003 ^p
<i>Selliguea griffithiana</i> (Hook.) Fraser-Jenk.	HY	1046–3016	w,t1,t2,t3,t4,t5	13-070-046 ^p , 13-071- 001 ^p , 13-073-003 ^p , 13-076-084 ^s , 13-077- 106 ^p , 13-086-025 ^p , 13-088-048 ^p , 13-091- 004 ^p
<i>Selliguea incisocrenata</i> (Ching ex W.M.Chu & S.G.Lu) S.G.Lu, Hovenkamp & M.G.Gilbert*	NT	2957–3003	t1,t2,t3,t4	12-005-006 ^s
<i>Selliguea kachinensis</i> (Hovenkamp, S.Linds. & Fraser- Jenk.) (treated as <i>Arthromeris</i> <i>kachinensis</i> (Hovenkamp, S.Linds. & Fraser- Jenk.) Fraser-Jenk., Odyuo & D.K.Roy (Mao <i>et al.</i> , 2017)).*	HK&HY	1404–1715	t3,t4,t5	13-094-159 ^{l,s} , 14-031- 020 ^l , 14-047-022 ^{l,s}
<i>Selliguea majoensis</i> (C. Chr.) Fraser-Jenk.*	HK	1661–1665	t3	14-032-208 ^s
<i>Selliguea malacodon</i> (Hook.) S.G.Lu, Hovenkamp & M.G.Gilbert*	HK	3400–3601	g,w,r,t1,t2,t3	14-015-001 ^s
<i>Selliguea nigropaleacea</i> (Ching) S.G.Lu, Hovenkamp & M.G.Gilbert*	HY	2078–3138	t1,t2,t3,t4,t5	13-064-048 ^p , 13-064- 056b ^u , 13-064-058 ^s , 13-064-059 ^p , 13-066- 033 ^p , 13-069-016 ^u

TABLE 1. Continued.

	Transect	Elevation range (m)	Substrate	ID & herbaria
<i>Selliguea oxyloba</i> (Wall. ex Kunze) Fraser- Jenk.	NT&HK	1404–2659	t1,t2,t3,t4,t5	12-012-008 ^u , 14-031- 021 ^u
<i>Selliguea</i> <i>quasidivaticata</i> (Hayata) H.Ohashi & K.Ohashi*	HY	2804–3138	t1,t2,t3,t4,t5	13-064-046 ^P , 13-065- 041 ^s , 13-066-042 ^P , 13- 067-038 ^s , 13-075-006 ^s
<i>Selliguea rhynchophylla</i> (Hook.) Fraser-Jenk.	HK&HY	1360–3047	t1,t2,t4,t5	13-085-124 ^s , 14-051- 009 ^u
<i>Selliguea stewartii</i> (Bedd.) S.G.Lu, Hovenkamp & M.G.Gilbert*	HY	3133–3138	t1,t2,t3,t4	13-064-056 ^P , 13-066- 038 ^P , 13-067-036 ^P
<i>Selliguea tibetana</i> (Ching & S.K.Wu) S.G.Lu , Hovenkamp & M.G.Gilbert*	HY	2400–2400	t2,t3,t4,t5	13-080-103 ^s
<i>Tomophyllum</i> <i>donianum</i> (Spreng.) Fraser-Jenk. & Parris	NT&HY	2181–3133	r,t1	12-007-004 ^s , 13-066- 034 ^P , 13-075-010 ^s , 13- 083-079 ^P
<i>Tricholepidium</i> <i>normale</i> (D.Don) Ching	HK&HY	1046–2434	g,w,r,t1,t2,t3	13-080-106 ^P , 13-080- 107 ^u , 13-082-079 ^s , 13- 084-004 ^P , 13-084- 005 ^u , 13-084-006 ^u , 13-085-111 ^s , 13-086- 001 ^s , 13-086-014 ^P , 13- 087-097 ^s , 13-087- 098 ^P , 13-087-107 ^u , 13-088-031 ^s , 13-088- 063 ^s , 13-088-062 ^s , 13- 088-066 ^s , 13-089- 106 ^u , 13-090-007 ^s , 13- 091-001 ^u , 13-092- 002 ^u , 13-092-008 ^P , 13-093-012 ^s , 13-093- 013 ^P , 13-093-014 ^P , 13-103-264 ^s , 13-103- 268 ^s , 14-032-003 ^P , 14- 047-012 ^s , 14-047-014 ^s
<i>Tricholepidium</i> <i>venosum</i> Ching*	HY	2233–2600	r,t1,t2,t3	13-078-010 ^P , 13-080- 105 ^P , 13-083-077 ^P , 13-087-106 ^P

Certain similarities also emerged at the genus level. For example, *Dryopteris* and *Polystichum* within Dryopteridaceae both have large numbers of species and comprise 22% of the total fern species occurrence in the Holarctic floral region and, due to their preference for colder and more extreme habitats in general, also occur in high numbers at elevations above 3,800 m in this study.

In neighbouring countries such as China, *Polystichum* is the most species-rich genus and occurs mostly in subtropical and temperate mountainous regions (Li *et al.*, 2008). The genera *Athyrium*, *Acystopteris*, *Huperzia* and *Hymenophyllum*, distributed mainly in the northern hemisphere and southern temperate regions, have been observed above 3,100 m, which corresponds to the elevation of the lower reaches of evergreen *Abies* forest in northern Myanmar. *Spinulum* is found only above 3,500 m in northern Myanmar, while the other genera can be found down to around 850 m in the subtropical moist hardwood forest. *Tomophyllum* and *Arthromeris* have been recorded in the Evergreen Fagaceae Forest and *Abies-Rhododendron* Forest between 1,000 m and 3,000 m in this study; those genera have a wide range of distribution and are known from regions mostly in tropical Asia and the west Pacific Islands as well as some in China and the Himalaya.

When compared to the previous records of ferns for Myanmar by Dickason (1946) and Nwe *et al.* (2016), and Indian pteridophytes checklist by Fraser-Jenkins *et al.* (2016), 125 additional fern species are recorded in this study (TABLE 1). We are aware that an accurate statement of which of these are new records for Myanmar would involve a much more comprehensive assessment of fern literature from neighboring regions, taxonomic monographs, and a more thorough assessment of the accuracy of the identifications of the ferns in the previous literature. This is beyond the scope of this study. In addition, *Selliguea kachinensis* Hovenkamp, S.Linds., Fraser-Jenk. (Polypodiaceae) has recently been described (Khine *et al.*, 2016). It was found in Northern Myanmar at an elevation between 1300 m and 1700 m in evergreen broadleaved forest. A new combination for this species as *Arthromeris kachinensis* (Hovenkamp, S.Linds. & Fraser-Jenk.) Fraser-Jenk., Odyuo & D.K.Roy in Mao *et al.* (2017) has also been published. Phylogenetic research to investigate whether *Arthromeris* should be recognized as distinct from *Selliguea* is ongoing (Hovenkamp, pers. comm.).

Patterns of species richness.—Species richness by elevation for the two areas declines at both lower and higher altitudes showing an unimodal pattern (Fig. 3). This same pattern has been found in the central Himalayas in Nepal (Bhattarai and Vetaas, 2006) and in plot-based sampling from numerous other tropical mountain areas (Hemp, 2002 in Tanzania; Krömer *et al.*, 2005 in Bolivia; Kluge *et al.*, 2006 in Costa Rica; Grytnes and Beaman, 2006 in Borneo; see Kessler *et al.*, 2011 for a worldwide comparison). The prominent climatic factors for fern and lycophyte species richness are temperature and water availability (O'Brien, 1998), hence the richness peak occurs at the elevation with moderate temperature and high humidity, thus differ between the gradients. Hence, the elevational position of richness peaks, as well as the maximum number of species per plot, strongly differs between the two areas in this study. Species richness per plot at NT did not exceed 22 species, while at HR we recorded more than double that number (N=49, Fig. 3). In addition, the total number of species recorded along each gradient at HR was far higher (262 species) than at NT (85 species). At first glance this pattern may seem surprising as, in general, species richness should decline towards higher

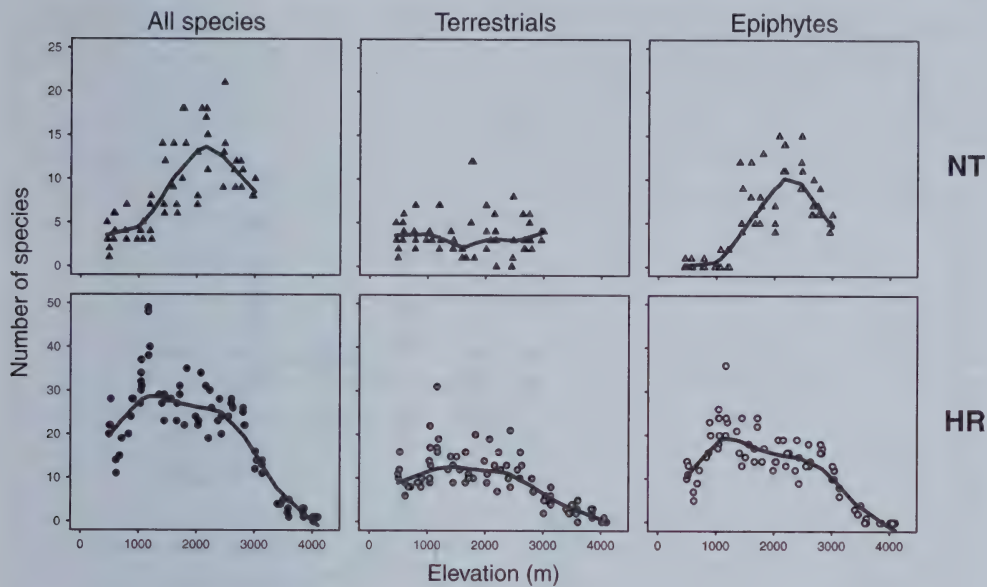


FIG. 3. Elevational patterns of fern species richness for all species, terrestrial and epiphytic life forms in the northwestern transect (Natma Taung; NT) and northern transect (Hponkanrazi + Hponyinrazi; HR). The trend lines were set by distance weighted least square smoothing (LOWESS).

latitudes, i.e., with increasing distance from the tropics. This is explained by the climatic setting of both gradients: the NT transect stretches down to the exceptionally dry intramontane basin of central Myanmar, and it receives less rainfall in Monsoon periods reflecting low annual precipitation and thus less ambient humidity (Fig. 2). Moreover, the elevation with maximum species richness strongly differs between both gradients (in NT 2,200 m, in HR 1,200 m). This difference may be explained by a mountain mass effect (see e.g., Leuschner, 1996): in the higher mountain ranges in the north, to which the HR gradient belongs, the temperature belts shift upwards, which may be the decisive factor influencing the elevation of the maximum species richness. Thus, when aligned to temperature rather than elevation, both peaks of species-richness lie at 15°C–17°C of mean annual temperature (Fig. 4), consistent with the findings from multiple fern elevational gradients worldwide (Kessler *et al.*, 2011).

As found in other elevational fern richness studies, the pattern found in this study is driven by the epiphytic life form (Fig. 3). Their elevational richness trend was more pronounced than for terrestrial species, rendering them more susceptible to the steep change of environmental condition along the elevational gradient, especially with respect to temperature and humidity (Kluge *et al.*, 2006; Ding *et al.*, 2016). The richness of epiphytic species per plot was higher than terrestrial species, reaching up to 34 species per 400 m²,

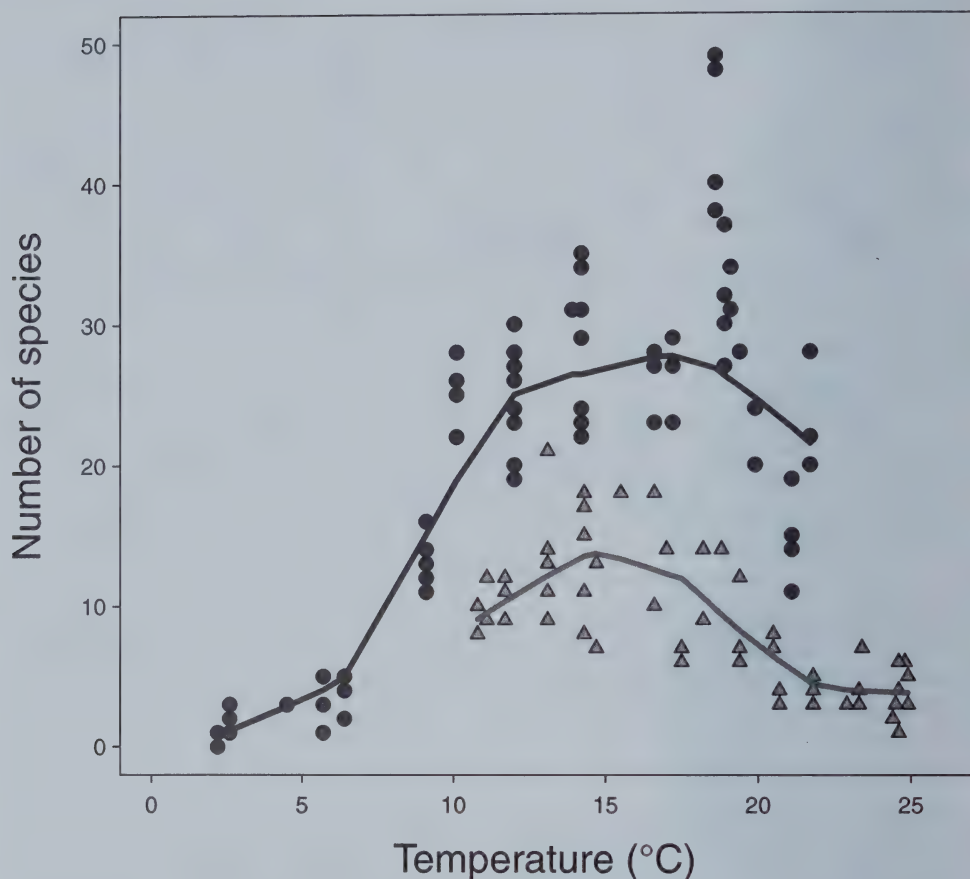


FIG. 4. Species richness pattern against mean annual temperature; Natma Taung (NT in triangles) and Hponkanrazi + Hponyinrazi (HR in circles). The trend lines were set by distance weighted least square smoothing (LOWESS).

at mid elevations at about 1,200 m in the HR transect, and 16 species at about 2,400 m elevation. However, in total 199 species from both transects were terrestrial species, whereas 162 were epiphytic species, thus overall more terrestrial species were recorded across the gradient. This is due to microhabitat variability, which is spatially much coarser for terrestrial species, thus capturing less variability per plot, in contrast to epiphytic microhabitats, which are more variable within one plot due to the complex morphological structure of host trees (Kluge and Kessler, 2011). Thus, epiphytic species should be more evenly distributed than terrestrial species, resulting in a higher number of occupied plots per species for epiphytes. This has been tested with the distribution data of this study by counting the mean number of plots occupied by terrestrial and epiphytic species, and indeed

epiphytic species on average were present in a significantly higher number of plots than terrestrials (6.8 vs. 4.0, Wilcoxon rank sum test: $p < 0.001$).

At low elevations, high humidity and its potential benefits for fern and lycophyte richness were offset by high temperatures and therefore high evapotranspiration, whereas towards the upper part of the gradient fern and lycophyte species richness may be limited by low temperatures, especially frost events (Bhattarai, Vetaas, and Grytnes, 2004).

CONCLUSION

This first and most comprehensive list of ferns from the mountain forests of northern Myanmar is a contribution to the upcoming Flora of Myanmar and a first contribution to the Myanmar element in aiding our understanding of the "East Himalaya-Yunnan biodiversity hotspot". On comparing this study to fern floras of other mountainous areas of South East Asia and other tropical mountains, the pattern of lower diversity at lower and higher elevations and of epiphytes dominant in cloud forests is confirmed. As ferns, and especially epiphytic ferns, are well-established indicators of habitat status and landscape fragmentation, this list may support any attempts for a better nature conservation policy in Myanmar. Clearly, this is just the first step towards a country 'Flora', which already exist or are in production for all neighboring countries within the Himalayan region. This work may help to induce further research on species richness and composition, especially in the still largely untouched mountain forest ecosystems bordering the Himalaya, the Tibetan highlands, and Yunnan.

ACKNOWLEDGEMENTS

Although most of the identifications were done by the co-authors of this publication, we give our heartfelt thanks to Peter Hovenkamp, Alan R. Smith, Marcus Lehnert, Shi-Yong Dong and Yea-Chen Liu who determined parts of collections from Chin State and Kachin State, Myanmar. We are grateful for the cooperation of Dr Nyi Nyi Kyaw, Win Naing Thaw, Dr Naing Zaw Htun, Myint Kyaw, Law Shein and staff members of the Forest Department, Ministry of Natural Resources and Environmental Conservation, Nay Pyi Taw, Myanmar. Field work was supported through grants of the German Research Council (DFG), the first author's PhD scholarship is financed by the German Academic Exchange Service (DAAD). RBGE is supported by the Scottish Government's Rural and Environment Science and Analytical Services Division.

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***Vittaria graminifolia* (Pteridaceae) and *Didymoglossum petersii* (Hymenophyllaceae) in Broxton Rocks, GA**

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ABSTRACT.—We report on the occurrence of independent gametophytes of *Didymoglossum petersii* and both gametophytes and sporophytes of *Vittaria graminifolia* in the Broxton Rocks Preserve of southern Georgia. This is the first time sporophytes of *V. graminifolia* have been observed in the United States. In order to unambiguously identify both taxa, we extracted DNA for each. In the case of *V. graminifolia*, we used BLAST to compare our results to sequences in GenBank for two plastid loci (*rbcL* and *rpoA*) to determine its affinities. Because there are no GenBank data for *D. petersii*, it was necessary to collect an additional specimen of this species for comparison in a phylogenetic analysis. Results confirm the identity of each specimen and provide insight into the biogeographic history of *D. petersii*.

KEY WORDS.—Filmy fern, shoestring fern, sporophyte, gametophyte, outcrops

Vittaria graminifolia Kaulf. and *Didymoglossum petersii* (A. Gray) Copel. are in two distantly related families of ferns, yet they share an enigmatic feature: the ability of their gametophytes to form long-lived populations absent of sporophytes (Bray, 1996; Farrar, 1993a). Archeologist Frankie Snow and botanist Carl Taylor recently noted small populations of two fern species in the Broxton Rocks Preserve of Southern Georgia (*pers. comm.*). One population contained gametophytes of *D. petersii*, which had been previously reported as growing in the preserve, while a second population had sporophytes and gametophytes of an unreported vittarioid species. Based on the ranges of vittarioid species near the area, the second population was thought to be either 1) a northern range extension for *V. lineata* (L.) Sm., which grows in Florida in the U.S., 2) a rare population of *V. graminifolia*, or 3) the first account of mature sporophytes of *V. appalachiana* Farrar and Mickel, which grows only as gametophytes throughout the Appalachian Mountains. Given that the spores from the specimen collected at Broxton rocks were trilete, a defining feature of *V. graminifolia*, as opposed to monolete, which is characteristic of *V.*

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lineata (Farrar, 1993a), we predicted that these sporophytes were likely *V. graminifolia* rather than *V. lineata* or *V. appalachiana*. What follows is a brief description of each species, a history of their collection, notes on the ecology of the site in which they were found, and results of a molecular analysis used to identify the two Broxton Rocks specimens.

Vittaria graminifolia.—This species grows mainly in the neotropics of Central and South America, where it readily produces sporophytes and is predominantly epiphytic. In the U.S., *V. graminifolia* has a chequered history of misidentification and collection. Edgar T. Wherry first reported the species as growing in Florida in his book the *Southern Fern Guide* (1964). Unfortunately, the identification proved to be incorrect, as Gerald Gastony later concluded that Wherry's specimen, as well as one Gastony himself had collected in the swamps of Collier County, FL, were both actually *V. lineata* based on morphological characters described by Tryon (1964; Gastony, 1980).

The first correctly identified specimen of *V. graminifolia* in North America was reported some ten years later, found by Donald Farrar and Garry Landry in St. Helena Parish, Louisiana (1987). They observed populations of *D. petersii*, which grew as sporophytes, and *V. graminifolia*, the latter only as independent gametophytes. The populations of both species were found growing on the buttresses of beech trees (*Fagus grandifolia* Ehrh.) and were identified based on allelic banding patterns, as well as distinctive morphology (Farrar and Landry, 1987).

Didymoglossum petersii.—This species has also been reported in the neotropics. Though apparently somewhat less widespread than *V. graminifolia*, the two have been reported in several of the same countries, including Guatemala, Costa Rica, El Salvador, and Mexico (Mickel and Smith, 2004). *Didymoglossum petersii* has several documented populations in the United States as well, in the southern Appalachian Plateau and Boston Mountains of Arkansas (Farrar, 1993b). The gametophytes of this species are filamentous and long-lived, thus enabling gametophytic populations to exist in the absence of sporophytes. In Arkansas, for example, independent gametophytes were observed growing some 50 km from the nearest known population of sporophytes (Bray, 1996).

Unfortunately, the gametophytes for this species are morphologically indistinguishable from many Hymenophyllaceae species with the same growth habit, such as the widespread and sporophyteless *Crepidomanes intricatum* (Farrar) Ebihara & Weakley. Although *D. petersii* is listed as occurring in Broxton Rocks based on the discovery of sporophytes there (Chafin, 2007; Edwards *et al.*, 2013), the presence of independent gametophyte colonies that lack sporophytes necessitates the use of genetic markers to determine whether these populations are *C. intricatum*.

Geography and ecology.—Both *V. graminifolia* and *D. petersii* were found growing together in Broxton Rocks Preserve, located in Coffee County, Georgia, in July of 2015. The preserve is owned by the Nature Conservancy and supports a unique ecosystem in the Atlantic coastal plain. While much of the area is dominated by longleaf pine (*Pinus palustris* Mill.), large sandstone

TABLE 1. Voucher and accession information for specimens sequenced in this study.

Species	Specimen location	Collector(s) & collection date	Tissue source & voucher location	Voucher number
<i>Didymoglossum petersii</i>	GA, Coffee Co.	J. Pinson, S. Chambers 2015	Field collected FLAS	FLAS 261024
<i>Didymoglossum petersii</i>	AL, Winston Co.	J. Pinson, S. Chambers 2017	Field Collected SEL	SEL113690
<i>Didymoglossum petersii</i>	TN, Blount Co.	E. Wofford 1999	Herbarium LSU	LSU00070729
<i>Vittaria graminifolia</i>	GA, Coffee Co.	J. Pinson, S. Chambers 2015	Field collected FLAS	FLAS 261025

outcrops also punctuate the landscape. These outcrops comprise the largest extrusion of what is known as the Altamaha Grit formation, a layer of sandstone covering 15,000 square miles, that ranges in age from the Oligocene epoch (33.9–23mya) to the Pleistocene epoch (2.6mya–11,700ya) (Huddlestun, 1988; Edwards *et al.*, 2013). The Broxton Rocks preserve is the only place where the Altamaha Grit sandstone has been exposed through erosion, creating desert-like conditions on its flat-topped surface and exposed rock outcrops below.

Along the face of these exposed outcrops are small crevices in the rock that harbor the populations of ferns examined here, which are often growing in close proximity to one another. Similar outcrops exist throughout the Appalachian Mountain Range and Plateau and provide habitat for other fern species that exhibit a pattern of spatially separated sporophytes and gametophytes (Farrar, 1967; Pinson *et al.*, 2017). These Appalachian outcrops are known to buffer seasonal and daily temperature variation (Chambers and Emery, 2016; Farrar, 1998) and provide extremely shaded conditions. Thus, the outcrops and crevices present in the Broxton Rocks preserve likely serve a similar function as the Appalachian outcrops by protecting the ferns from fluctuations in temperature and exposure to direct sunlight.

MATERIALS AND METHODS

Taxonomic sampling.—Specimens of the two unknown taxa were collected in 2015 with Frankie Snow, who helped guide us to the populations. Samples were dried using silica gel (Chase and Hills, 1991). An additional specimen from a known population of *D. petersii* producing sporophytes in Winston County, AL was collected during the summer of 2017 to serve as a comparison in the phylogenetic analysis, and an additional herbarium specimen of *D. petersii* from Blount County, TN was used for the same purpose. Field-collected specimens were deposited in either the Florida Museum of Natural History (FLAS) or Marie Selby Botanical Gardens (SEL) herbaria (Table 1).

Extraction and amplification.—Total genomic DNA was extracted using a DNeasy Plant Mini Kit (Qiagen, Germany). Lab techniques used existing

primers and protocols for polymerase chain reaction (PCR) from previous analyses of *rbcL* (Korall *et al.*, 2006) and *rpoA* (Pinson and Schuettelpelz, 2016). Each 25 μ L reaction contained 4.5 μ L of purified water, 12.5 μ L of Amplitaq Gold DNA polymerase (Applied Biosystems), 2 μ L of each primer (10 μ M), and 4 μ L of DNA. Thermocycling conditions followed those of Pinson and Schuettelpelz (2016). PCR products were then visualized on agarose gels. Sequencing was performed either by the University of Florida Interdisciplinary Center for Biotechnology Research (Gainesville, FL) or Eurofins Genomics (Louisville, KY). Sequences were assembled in Geneious v. 7.1.8 (Kearse *et al.*, 2012).

Phylogenetic analyses.—In order to confirm the identities of the two populations, we conducted two separate analyses. For the population suspected to be *V. graminifolia*, we used a nucleotide BLAST search to identify the sequences, because many accessions of *Vittaria* species (including *V. graminifolia*) have been sequenced for these loci and are available on GenBank. For the population believed to be *D. petersii*, we used a tree-building approach, because there are no sequences available for this taxon and relatively few for *Didymoglossum*. We conducted a phylogenetic analysis that included our newly-generated sequences, plus *rbcL* sequences downloaded from GenBank for: *Didymoglossum krausii* (Hook. & Grev.) C. Presl, *D. reptans* (Sw.) C. Presl, *D. hymenoides* (Hedw.) Copel., *D. tahitense* (Nadeaud) Ebihara & K. Iwats., *D. motleyi* (Bosch) Ebihara & K. Iwats., *D. lorencei* (Tardieu) Ebihara & Dubuisson, *D. ovale* E. Fourn, and *Polyphlebium angustatum* (Carmich.) Ebihara & Dubuisson, which served as an outgroup. Sequences were aligned by hand using Mesquite (v. 3.10; Maddison and Maddison, <http://mesquiteproject.org>). To determine which model best fit our data, we ran PartitionFinder (v 1.1.1 Lanfear *et al.*, 2012). We then performed a maximum likelihood analysis with a GTR+G model of substitution in RAxML (v. 8.0.0 Stamatakis, 2014), completing 1,000 bootstrap replicates and a search for the best tree in a single run (option *-f a*). The outgroup was constrained to be *P. angustatum*. Our alignment and tree files were uploaded to TreeBASE (submission ID 21631).

RESULTS

Based on our GenBank BLAST search, the *Vittaria* specimen collected at Broxton Rocks is *Vittaria graminifolia*. Both the *rbcL* and *rpoA* sequences from our field-collected specimens were matched at 99% identity to other *V. graminifolia* specimens on GenBank. For *D. petersii*, the full *rbcL* locus was amplified for the specimen collected at Broxton Rocks, as well as for an additional specimen collected in northern Alabama (Table 1). We had little success with amplifying sequences from herbarium samples but were able to amplify half of *rbcL* from one such specimen. The Broxton sample is resolved with 100% bootstrap support as being sister to a clade containing the two other *D. petersii* individuals (Fig. 1).

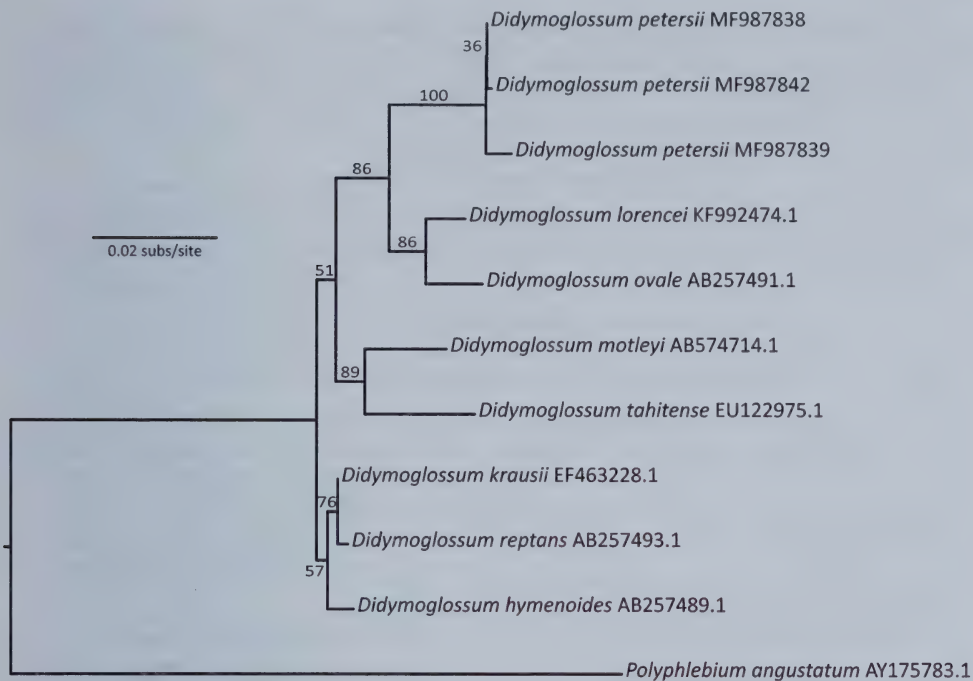


FIG. 1. The best tree topology based on a maximum likelihood analysis performed in RAxML. The *D. petersii* sample collected in Broxton (MF987839) is supported with 100% bootstrap as being sister to a clade containing two additional *D. petersii* taxa.

DISCUSSION

Vittaria graminifolia.—Based on our results, the sporophytic tissue collected from Broxton Rocks, GA belongs to *Vittaria graminifolia*. This is the first time a sporophyte of this species has been confirmed as growing in the United States. According to the Flora of North America, the closest population producing viable sporophytes is likely in Cuba (Farrar, 1993a); we therefore infer that the population at Broxton Rocks is the result of long-distance dispersal from that island or elsewhere in the tropics. However, studies should be conducted to examine the population structure of *V. graminifolia* and should include samples from this location and from the population reported from Louisiana (if it still exists). Such studies will help to support or refute our hypothesis concerning the origin of the Broxton Rocks plants and may help to determine how individuals in this population relate to those in Louisiana, which are solely gametophytes. The habitat differences between the population in Georgia (protected sandstone outcrops) and the one lacking sporophytes in Louisiana (beech tree buttresses) suggest that fine-scale environmental conditions may strongly influence the production of sporophytes in this species. It is also possible that the Louisiana population was founded by the long-distance dispersal of a single spore, and the lack of sporophytes there may represent an inability to self. It has been hypothesized that the more vegetatively prolific

morphology of some epiphytic fern gametophytes, including these species, is an adaptation to prolong their lifespan, and that these gametophytes can therefore 'wait' for long periods of time until the arrival of one or more conspecific spores permits outcrossing (Dassler and Farrar, 2001). The population in Louisiana may have been playing just such a waiting game.

Didymoglossum petersii.—The affinities of Hymenophyllaceae species in the eastern United States are poorly understood, but our analysis confirms that *D. petersii* is present in Georgia. This is the first time this species has been included in a phylogenetic analysis. Our maximum likelihood tree resolves *D. petersii* as being most closely related to a clade containing both *D. ovale* and *D. lorencei*. While the former grows in Central and South America, *D. lorencei* grows on the Mascarene Islands of the Paleotropics. Even more surprising is the more distant relationship in our tree of *D. petersii* with *D. krausii*, which grows nearby in southern Florida. These relationships suggest multiple colonization events of North America via long-distance dispersal by species already established in the tropics. *Didymoglossum* is estimated to include about 30 species in total (PPG 1, 2016), and sequencing of additional species than the few currently available and included here will be essential for clarifying the biogeographic history of this group.

Hymenophyllaceae in North America.—There are several other species of Hymenophyllaceae present in North America, but there are few for which molecular data are available. Of the eleven purportedly growing in North America, only three have GenBank accessions from populations in the U.S., including our present submission of *D. petersii*. This makes it difficult to infer the biogeographic history of the family as a whole in this region. Phylogenetic and historical reconstructions are further confounded by differences in distribution patterns of the life cycle stages and life history traits that make it difficult to positively identify gametophyte and sporophyte specimens to species (as is demonstrated by the species discussed here; see introduction above). Some species have limited distributions with sporophytes present, which is the case for most of the species growing in the southeastern United States (e.g. *Didymoglossum krausii*, *Trichomanes holopterum* Kunze). In contrast, *Hymenophyllum tayloriae* Farrar and Raine and *Crepidomanes intricatum*, both endemic to the U.S., are two of three fern species for which there are no known sporophytes anywhere in the world (Pinson *et al.*, 2017), the latter having the largest distribution of any of the North American Hymenophyllaceae (Farrar 1993b). Finally, there is evidence of dispersal to North America from at least three centers of diversity. Both *C. intricatum* and another species found in the northwestern U.S. and Canada, *Hymenophyllum wrightii* Bosch, have either conspecifics or close relatives growing in Asia, whereas *Hymenophyllum tunbridgense* L. Sm. grows in both the Appalachian Mountains and in Europe (Duffy, Stensvold, and Farrar, 2015; Ebihara, Farrar, and Ito, 2008; Farrar, 1967). The remaining species are either endemic to eastern North America (i.e. *H. tayloriae*, *Vandenboschia boschiana* (J.W. Sturm ex Bosch) Ebihara & K. Iwats., and *C. intricatum*) or have additional distributions in Central and/or South America (Farrar, 1993b). These

complications of life history and distribution underscore the need for further work on filmy ferns in North America, to understand both the relationships of these species as well as their biogeographic history.

ACKNOWLEDGEMENTS

We thank Carl Taylor for bringing the population of *Vittaria graminifolia* at Broxton Rocks to our attention and Frankie Snow for kindly guiding us through the preserve and showing us where both populations were located.

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APPENDIX 1. INDIVIDUALS USED IN THIS STUDY, WITH INFORMATION PROVIDED IN THE FOLLOWING ORDER: SPECIES NAME, VOUCHER INFORMATION, PLACE OF ORIGIN, AND GENBANK ACCESSION NUMBERS.

Didymoglossum hymenoides (Hedw.) Copel., Dubuisson HG2004-27 (P), Guadeloupe, AB257489.1; *Didymoglossum krausii* (Hook. & Grev.) C. Presl, Schuettzel 220 (DUKE), Ecuador: Napo Province, EF463228.1; *Didymoglossum lorencei* (Tardieu) Ebihara & Dubuisson, J.-Y. Dubuisson HR 2002-7 (P, REU), Reunion, KF992474.1; *Didymoglossum motleyi* (Bosch) Ebihara & K. Iwats., TNS:759342, Japan, AB574714.1; *Didymoglossum ovale* E. Fourn., T.A.Ohsawa 178-10 (TNS), Bolivia, AB257491.1; *Didymoglossum petersii* (A. Gray) Copel., Eugene B. Wofford s.n. (LSU), United States: Tennessee, MF987838; *Didymoglossum petersii* (A. Gray) Copel., Jerald Pinson 2 with Sally Chambers (FLAS), United States: Georgia, MF987839; *Didymoglossum petersii* (A. Gray) Copel., JP51 (SEL), United States: Alabama, MF987842; *Didymoglossum reptans* (Sw.) C. Presl, Lamieux 2275, Costa Rica, AB257493.1; *Didymoglossum tahitense* (Nadeaud) Ebihara & K. Iwats., J.Nitta005, French Polynesia: Moorea, EU122975.1; *Polyphlebium angustatum* (Carmich.) Ebihara & Dubuisson, M. Kessler 10957, Bolivia, AY175783.1; *Vittaria graminifolia* Kaulf., Jerald Pinson 1 with Sally Chambers (FLAS), United States: Georgia, MF987840, MF987841.

ERRATUM

AFJ volume 107 issue 3, pp. 156–191 (2017)

Corrections to *American Fern Journal* article entitled **Eleven New Scaly Tree Ferns (*Cyathea*: Cyatheaceae) from Peru** by Adrian Tejedor and Gloria Calatayud follow:

p. 157, line 1 of first paragraph should read: Field trips in Peru were completed during March 2014, March, 2015, and October 2017.

p. 157, first paragraph of Taxonomic Treatment: replace “July 2016” with “October 2017”.

p. 164, line 8, replace “July 2014” with “October 2017”.

p. 166, line 6, replace “July 2014” with “October 2017”.

p. 173, line 21, replace “August 2014” with “October 2017”.

p. 182, line 25, replace “July 2014” with “October 2017” and replace “5621” with “6021”.

p. 184, line 11, replace “July 2014” with “October 2017” and replace “5975” with “5971-B”.

p. 184, 5th line from bottom, replace “date” with “20 October 2017” and replace “5615” with “6015”.

p. 189, modify line 11 of Acknowledgements to read: “research permits N° 003-2014-SERNANP-DGANP-JEF and N° 326-2017-SERFOR/DGSGSPFFS, under which field collections were made. We”

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FERN JOURNAL

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